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BRIEFING ON THE SWEDISH PROGRAM ON NUCLEAR WASTE MANAGEMENT

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MEMORANDUM OF THE CHAIRMAN

To Members of the Senate Committee on Energy and Natural Resources:

The program the United States has undertaken with the passage of the Nuclear Waste Policy Act of 1982 is an unprecedented effort in technology, in environmental management and in Federal-State-tribal relations. The nuclear waste program will stretch over a generation, will spend perhaps $30 billion over that period and will result in facilities capable of effectively and safely isolating nuclear waste from the biosphere for hundreds of thousands of years without the need for further human intervention. It is a task that is absolutely unique in its nature and in its enormity.

The United States is not the only nation in the world that is embarked on this effort, although the U.S. program is certainly the largest and most dramatic. Sweden, France, Germany and the United Kingdom are all actively engaged in developing the technology for the long-term management of nuclear waste and, in varying measure, in taking definitive steps to implement that technology.

Perhaps the most comprehensive and advanced of these European programs is the one underway in Sweden.

Because of this, Senator James A. McClure and Senator Alan Simpson joined with me in extending an invitation to officials responsible for the Swedish program to visit the United States and to brief Congress on the Swedish experience. We all felt that it would be particularly helpful to Congress in overseeing and charting the course of the U.S. program if we were able to take advantage of the experience of other nations who have struggled with this issue.

The briefing for the Senate by the Swedish delegation took place on January 22, 1987, and on the next day a briefing was held for the House of Representatives.

In Sweden, a special private company, the Swedish Nuclear Fuel and Waste Management Company (SKB), has been set up to manage the storage and disposal of nuclear waste. Sweden already has facilities in operation or under construction that can handle all of their waste for at least a number of decades. Sweden has been able to build a national consensus of support for each stage of their program.

In 1985, Sweden opened an interim storage facility, called the CLAB, where spent fuel and high-level waste will be cooled prior to final disposal. This facility is very similar in design and concept to the monitored retrievable storage (MRS) facility that is under consideration as a part of our own nuclear waste policy.

Sweden has begun the design and site selection process for a geologic repository in granite for final disposal of these wastes, but they do not intend to characterize sites until much later in the program. Sweden has approved one repository concept, but they have also allowed time to seek other alternatives. Sweden also has a repository for disposal of low- and intermediate-level waste that is under construction and scheduled for operation early in 1988.

As will be evident to readers of this document, the Swedish delegation provided Congress with an excellent overview and explanation of their very fine program. The Swedish experience shows clearly that competence, dedication, and a willingness to address the concerns of the public forthrightly can produce a range of acceptable solutions to difficult problems, even problems as difficult as the disposal of nuclear waste.

J. BENNETT JOHNSTON, *Chairman.*

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BRIEFING ON THE SWEDISH PROGRAM ON NUCLEAR WASTE MANAGEMENT

THURSDAY, JANUARY 22, 1987

WASHINGTON, DC.

The committee met, pursuant to notice, at 2:55 p.m., in room SD-366, Dirksen Senate Office Building, Hon. J. Bennett Johnston, chairman, presiding.

OPENING STATEMENT OF HON. J. BENNETT JOHNSTON, A U.S. SENATOR FROM THE STATE OF LOUISIANA

The CHAIRMAN. The meeting will come to order.

We are very pleased today to have some experts from Sweden who are much further along with their nuclear waste policy and a real solution to that problem than we are here in the United States. They are not only knowledgeable, but experienced, and we are deeply indebted to Mr. Bjurstrom and Mr. Nyquist—do I pronounce that right?

Mr. NYQUIST. That is correct.

The CHAIRMAN. We are indebted to you for coming here and sharing with the committee your experience with what we call MRS, or monitoned retrievable storage. We can profit a great deal by your experience.

We also hope later in the year, if it is possible, to have a visit to Sweden to see what you have.

So, gentlemen, let me welcome you. Let me thank you profusely for being here and sharing with us your great fund of information.

STATEMENT OF CARL-ERIK NYQUIST, PRESIDENT, THE SWEDISH STATE POWER BOARD, AND CHAIRMAN, SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY (SKB), STOCKHOLM, SWEDEN, ACCOMPANIED BY DR. STEN BJURSTROM, PRESIDENT, SKB; PER-ERIC AHLSTROM, RESEARCH DIRECTOR, SKB; AND HAROLD AHAGEN, PROJECT MANAGER, SKB

Mr. NYQUIST. Mr. Chairman, members of the committee, my colleagues and I feel honored at having been invited by you to inform about the Swedish program for radioactive waste management.

I apologize if I brought the bad weather with us, but with the heartily warm welcome we have received, we feel very comfortable here.

As you know, I have responsibility for these matters as President of the Swedish State Power Board and as Chairman of the Board of the Swedish Nuclear Fuel and Waste Management Company, SKB,

which is owned by the nuclear power utilities in Sweden with the State Power Board as the main owner.

My complete introduction has been distributed to you. I would like to emphasize some parts. I will also refer to the figures at the end of my paper. So if you have the paper, you can follow it.[1]

First of all, I should introduce my colleagues here. This is Dr. Bjurstrom. He is President of the Waste Management Company; and Mr. Ahlstrom, who is Research Director of the same company; and Mr. Ahagen here is Project Manager of SKB and is now working temporarily in the United States.

As you can see from figure 1, the location of Sweden is far away north in Europe.

On figure 2 some data of the Swedish energy profile is shown. As you can see, electricity covers a fairly large part of the total energy consumption in Sweden, about 30 percent. It is mainly based on hydropower and nuclear power, about 50 percent each. The State Power Board, which I am responsible for, produces about one-half of the total electricity in Sweden. The other half is generated in plants owned by industries and municipalities.

On figure 3 you can see that nuclear is produced at four sites with all together 12 units. Nine units are boiling water reactors (BWR) manufactured by ASEA, Sweden, and three units are pressurized water reactors (PWR) manufactured by Westinghouse.

The nuclear reactors are operating very well, which is illustrated on figure 4. The availability is very high compared with the world average.

Although the Swedish plants show an excellent performance, the Swedish Parliament decided in 1980 to phase out nuclear power in 2010 at the latest. This decision was based upon the referendum on the nuclear issue in 1980 following the accident at Three Mile Island.

Following the Chernobyl accident, the possibility of replacing the nuclear power even earlier than 2010 is now being studied. Most important in the Swedish nuclear power legislation is the Act on Nuclear Activities from 1984. This law stipulates that the owner of a nuclear reactor shall bear the responsibility for all steps necessary for safe handling and final disposal of all radioactive residues from nuclear energy production. This includes financing of the total cost.

To fulfill the obligations according to the law, the four utilities that operate nuclear reactors in Sweden have formed a special company, the Swedish Nuclear Fuel and Waste Management Company, SKB. SKB is responsible for all handling, transportation, and storage—temporary and permanent—of the spent fuel and radioactive waste from the nuclear powerplants.

The regulation and supervision of nuclear power production and radioactive waste management are undertaken by three separate authorities, which you can follow better on figure 5. The three are:

First, the Swedish Nuclear Power Inspectorate, which supervises the safety in all nuclear activities in Sweden.

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[1] The prepared statement of Mr. Nyquist begins on pg. 7.

The second is the National Institute of Radiation Protection, which takes care of radiation protection.

And the third is the National Board of Spent Nuclear Fuel, which is responsible for financing of nuclear waste management. This is a special authority for Sweden.

The Swedish system for handling and disposal of radioactive residues is planned and designed to meet a very high standard in terms of safety and environmental impact. It has been developed in order to meet the following demands. If you look at figure 6, you can see how it is organized.

The following demands are:

The radioactive waste shall be disposed of in Sweden without reprocessing.

The waste problem shall be solved by the same generation that utilizes the electricity from the nuclear power stations.

The activities shall be conducted openly, with good public participation and insight.

For our first nuclear reactors, reprocessing was intended. Thus, our research work was directed to solve the problems associated with radioactive waste from reprocessing. This was also a stipulation in a special law at that time.

After the decision to phase out nuclear power, direct disposal of spent fuel was given highest priority. The concept for direct disposal of spent fuel in crystalline rock was approved by the Government in 1983 after extensive review by the Swedish authorities and by other experts in Sweden and around the world.

The implementation of the Swedish waste management program is now well underway. For the low- and medium-level waste from all nuclear powerplants, a final repository is under construction and will be taken into operation next year. For interim storage of spent fuel, an underground storage was taken into operation last year.

Various options for the final repository are now being studied. Dr. Bjurstrom will give you further details of the work and plans so far.

Talking a little about the costs: According to the Swedish law, all costs for the management of radioactive waste, including the decommissioning of the nuclear powerplants, have to be borne by the owners of these plants. The costs must be paid in advance, and they are covered by a fee on nuclear energy production determined annually by the Government. The fee is based on assumption that the nuclear plants will be operated during 25 years, while the expenses for the waste program will occur up to the middle of the next century.

The total cost for the back end of the nuclear fuel cycle is estimated to $6.5 billion US. The fee for the year 1986, as well as for 1987, is about 3 mills per kilowatt hour.

The CHAIRMAN. Dr. Nyquist, may I interrupt you at that point, because I have read your statement here and have some questions to ask you, and I do not want to run out of time before we have time to ask those questions. So if you would permit me to be that discourteous as to interrupt you to ask those questions——

Mr. NYQUIST. Certainly.

The CHAIRMAN. First of all, I notice you say it is the responsibility of the nuclear company to handle its waste through all cycles, and that you have a site in crystalline rock.

Mr. NYQUIST. That is true.

The CHAIRMAN. Now you have not picked a final disposal sight. Do you contemplate just one nuclear waste repository for a final repository?

Mr. NYQUIST. Dr. Bjurstrom.

Dr. BJURSTROM. Yes. That should be just one repository in Sweden, because the total amount of spent fuel up to the year 2010 will be around 8,000 tons of uranium, and it means we just need one repository. But we have not finally picked that site yet.

The CHAIRMAN. And as I understand it, your idea is to cool your waste down to, is it 100 degrees Fahrenheit, or Centigrade?

Dr. BJURSTROM. Centigrade.

The CHAIRMAN. And that will occur about 2010, or before?

Dr. BJURSTROM. Well, the main idea behind this is to keep it in interim storage for a period of around 30 to 40 years. During this period, as well the activity, that is the heat, will decay, decrease quite considerably. It means that it is much easier to handle after that.

The CHAIRMAN. Dr. Nyquist, do you really think that Sweden in the year 2010 will be able to follow through on its plan to do away with nuclear energy?

Mr. NYQUIST. The planning is well underway now, because it is just 25 years left. So I would say that the utilities in Sweden now are planning for replacing the nuclear power.

The CHAIRMAN. What would they replace it with?

Mr. NYQUIST. They must replace it, as I say, first of all they have an extensive conservation program to converting electricity to other energy forms. On the other hand, also, we must build many new coal condensing powerplants, large condensing powerplants, and it must be fired by coal or natural gas.

The CHAIRMAN. Is there a big supply of coal and natural gas in Sweden?

Mr. NYQUIST. Unfortunately, I must say there is no natural gas or coal in Sweden. We are still some hydropower yet left, and hydropower is most favorable. But then it is protected by all kinds of environmental protection.

The CHAIRMAN. Well, I am informed by people in the coal States in the United States that there is plenty of coal here. [Laughter.]

Mr. NYQUIST. Thank you. We may be able to import it.

The CHAIRMAN. And we will be happy to supply your needs.

Sweden is moving spent fuel twice, once to the CLAB and then to the final repository. Why have you done that?

Dr. BJURSTROM. Well, we have an interim storage. Basically it is for technical reasons. As we said, having an interim storage for a period of 30 to 40 years with a decay of the activity and a decrease of the temperature will make the final repository more economic and easier to handle. This is the main reason.

The second reason is that you need time to develop an optimum solution. You have to find the right site to understand it, and it takes some time, and it will be an advantage to have it in an interim storage for that.

The CHAIRMAN. I very much agree with you, and have made those same arguments here with our program. That is one reason we have the monitored retrievable storage. You call it CLAB, and we call it MRS. I think it amounts to very much the same thing, although I want to get into the details of that in your testimony. But it is a much easier thing to manage, and I do not know why everyone cannot see that in the Congress, when you cool these wastes down and the radioactivity goes down in an exactly parallel plane, you can probably tell me about that, but as I understand it the dropoff in heat and in radioactivity are exactly similar, the same decline line. And after something like, as I recall the testimony, something like 50 years it is cool enough both in terms of waste heat and in terms of radioactivity to handle much more easily. Am I correct in that?

Mr. AHLSTROM. Yes. I think basically you are correct. If you wait for about 30–40 years, you have a substantial decay in the heat, the residual heat in the spent fuel. There is no real sense to wait any longer, because then the decay of the heat is slower. So to have a comparable heat decay, you would have to wait for hundreds of years for the decay to get from 1 year to about 30 years.

The CHAIRMAN. I think Mr. Nyquist has talked about the cost. I think you said it was $6.5 billion for the overall program.

Mr. NYQUIST. Yes.

The CHAIRMAN. And I think it was 40 percent of the fee went to the final end of the cycle. Now does that mean 40 percent of the $6.5 billion is your cost of both interim storage and final storage?

Mr. NYQUIST. About 40 percent of the fees will cover the final disposal of spent fuel, and the rest, the 60 percent covers the rest of the handling of the interim storage, transportation, research, and also the decommissioning of the nuclear powerhouse.

The CHAIRMAN. Does that mean your total waste storage program is about $2.5 billion?

Mr. NYQUIST. Yes, that is correct.

The CHAIRMAN. That fee is similar to the United States, but the cost of final storage I think is going to end up being much greater in the United States. For one thing, we have three sites picked out now, and we are going to characterize all three, which means drilling big shafts, and it is going to cost about a billion dollars per site just to drill the shaft. I do not know why we did that, but we are doing that at great cost.

How much will it cost you to characterize your final site? Do you have a figure?

Dr. BJURSTROM. Yes, we have some figures. First of course we have to realize that the United States is 10 times bigger. You need much more drilling.

But anyhow, in Sweden we of course have a very round figure for the detailed characterization we are looking—we are doing in the 1990's, and we are talking about something like $50 million U.S., something like that.

The CHAIRMAN. $50 million?

Dr. BJURSTROM. $50 million, yes, something like that. Is that not correct? Per each site, yes.

The CHAIRMAN. Having interrupted you, I do not know whether I helped the process or not by interruption, but, Dr. Nyquist, did you

have further to add that you might finish, and then we will go to Dr. Bjurstrom.

Mr. NYQUIST. Yes, I have just a short statement. I would stress that a very important thing of this is that information to the public concerning the safety of the system is an essential part of the waste management program.

I would say no effort is saved to promote acceptance of our nuclear waste management program to the Swedish public. I would say, however, that much remains to be done to gain the public acceptance. We have met quite strong local opposition on several of our test sites. On the other hand, we have succeeded in finding sites for CLAB and a repository for radioactive waste test sites in the vicinity of the nuclear powerplants.

These sites are better accepted than those elsewhere. I think this is important. I also would stress that broad and open international cooperation is essential in solving technical problems of radioactive waste disposal, as well as for gaining public understanding and acceptance. We have had the pleasure of long-time cooperation with the United States and its Department of Energy. The cooperation has included work in the research and development field, as well as in exchange of information.

From the Swedish side we have found this very valuable, and are looking forward to continued cooperation with your experts.

On that, we can turn to the more technical side.

[The prepared statements of Mr. Nyquist and Dr. Bjurstrom follow:]

Briefing on

The Swedish Program on Nuclear Waste Management

for US-Congress Committees on
Energy and Natural Resources,
Environment and Public Works,
Interior and Insular Affairs,
Energy and Commerce.

By:
Mr Carl-Erik Nyquist,
Director General, Swedish State Power Board
and
Dr Sten Bjurström,
President, SKB

1987-02-02 SP-BD/MW

The Swedish Program for Radioactive Waste Management.
Briefing by Carl-Erik Nyquist, President of the Swedish State Power Board in the U.S. Congress 1987-01-22

Mr Chairman.
Members of the Committee.

My colleagues and I feel honoured at having been invited to you to inform about the Swedish Program for Radioactive Waste Management.

I have responsibility for these matters as President of the Swedish State Power Board and as Chairman of the Board of the Swedish Nuclear Fuel and Waste Management Company (SKB), which is owned by the nuclear power utilities in Sweden with the State Power Board as main owner.

My name is Carl-Erik Nyquist. Dr Bjurström is president of SKB and Mr Ahlström is the research director of the same company. Mr Åhagen is a project manager of SKB now working temporary in the US.

Figure 1 Sweden is a small country in Northern Europe with a population of 8.5 Million. It has an energy intensive industry and a fairly cold climate. Forestry, mining and hydro power resources have created a good base for the Swedish industrial development. Wellknown export products are steel, pulp and paper as well as Volvo and SAAB cars.

Figure 2 The Swedish energy profile is shown on figure 2. The corresponding data for USA are also given. As you can see, electricity covers a fairly large part of the total energy consumption in Sweden - about 30%. The electricity production, which in 1985 amounted to about 130 TWh, is mainly based on hydropower and nuclear power - about 50% of each.

The State Power Board produces about one-half of total electricity in Sweden. The other half is generated in plants owned by industries and municipalities.

Figure 3

Nuclear power is produced at four sites with all together twelve units as you can see on figure 3. Nine units are BWR manufactured by ASEA, Sweden, and three units are PWR manufactured by Westinghouse.

Figure 4

The nuclear reactors are operating very well, which is illustrated on figure 4, which shows the availability of the units compared with the world average as well as the U.S. figures.

Although the Swedish plants show an excellent performance no more nuclear power will be built in our country and the existing plants shall not be operated beyond the year 2010. This is in accordance with a decision of the Swedish Parliament. This decision was taken after an intensive debate on the nuclear issue in the 1970s and a referendum in 1980 following the TMI accident.

The Swedish Government's strategy for phasing-out the nuclear power is that the actual shut-down of the nuclear plants should start towards the end of the 1990s. Following the Chernobyl accident, the possibility of replacing the nuclear power even earlier than 2010 is being studied.

Phasing-out nuclear power will mean an exceptional economic burden on the Swedish society if this is done before the end of the economic lifetime of the reactors. Following present plans the reactors will be of an age between 25-30 years when they are taken out of operation. Therefore possibilities of conserving electricity as well as replacing electricity with other energy sources are now studied very carefully and comprehensively.

Most important in the Swedish nuclear power legislation is the "Act on nuclear activities" from 1984. This law stipulates that the owner of a nuclear reactor shall bear the responsibility for all steps necessary for safe handling and final disposal of all radioactive residues from nuclear energy production. This includes financing of the total cost. That law also stipulates that the owner of a nuclear reactor has - before a reactor is commissioned - to demonstrate a method for the handling and final disposal of spent nuclear fuel which is acceptable with regard to safety and radiation protection. He also has to provide for a comprehensive research and development program so that the best available methods can be deployed at all stages of the handling and storage of radioactive waste.

To fulfill the obligations according to the law, the four utilities that operate nuclear reactors in Sweden have formed a special company, the Swedish Nuclear Fuel and Waste Management Company (SKB). SKB is reponsible for all handling, transportation and storage (temporary and permanent) of the spent fuel and radioactive waste from the nuclear power plants. Furthermore, the company is responsible for the planning and construction of all facilities required and for necessary research and development work.

Figure 5 The regulation and supervision of nuclear power production and radioactive waste management are undertaken by three separate authorities, see figure 5.

The Swedish Nuclear Power Inspectorate (SKI) - corresponding to the Nuclear Regulatory Commission (NRC) in the United States - supervises the safety in all nuclear activities in Sweden.

Radiation protection is taken care of by the National Institute of Radiation Protection (SSI). In the United States these matters are handled by NRC, EPA (Environmental Protection Agency) and others.

Research for and financing of nuclear waste management is handled by the National Board for Spent Nuclear Fuel (SKN). This is a special authority for Sweden. In the United States these questions are as I am told handled within the Department of Energy (DOE).

Figure 6 The Swedish system for handling and disposal of radioactive residues is planned and designed to meet a very high standard in terms of safety and environmental impact. It has been developed in order to meet among others the following demands:

- The radioactive waste shall be disposed of in Sweden without reprocessing.
- In all essential respects, the waste problem shall be solved by the generation that utilizes the electricity production from the nuclear power stations.
- A decision on design of final repository shall be taken around the year 2000 and be based on a broad body of knowledge.
- The design of the system for waste management shall meet safe-guard requirements.
- The activities shall be conducted openly and with good public participation and insight.

Extensive research has been undertaken in Sweden since the mid-70s. It has resulted in concepts for final disposal of high level waste from reprocessed fuel as well as for direct disposal of spent fuel without reprocessing. For our first nuclear reactors reprocessing was intended. Thus, our research work was directed to solve the problems associated with radioactive waste from reprocessing. This was also a stipulation in a special law at that time.

Parallel to this, work was also started on direct disposal of spent fuel in order to achieve a system that could be controlled within Sweden and ensure sufficient capacity of the backend. After the decision to phase out nuclear power, this direction was given highest priority. The concept for direct disposal of spent fuel in crystalline rock (KBS-3) was approved by the Government in 1983 after extensive review by the Swedish authorities and by other experts in Sweden and around the world.

The implementation of the Swedish waste management program is now well under way. For the low- and medium-level waste from all nuclear power plants a final repository is under construction (SFR) and will be taken into operation next year. For interim storage of spent fuel an underground storage (CLAB) was taken into operation in 1985.

Various options for the final repository, is now being studied. Dr Bjurström will give you further details of the work and plans so far.

According to Swedish law all costs for the management of radioactive waste, including the decommissioning of the nuclear power plants, have to be born by the owners of these plants. The costs must be paid in advance and are covered by a fee on the nuclear energy production determined annually by the Government. The calculation of the fee is based on the assumption that the nuclear plants will be operated during 25 years. The fee will be paid during these years, while the expenses for the waste program will occur up to the middle of the next century.

The total cost for the back-end of the nuclear fuel cycle is estimated to 6.5 billion US$. This figure includes storage facilities for spent fuel and a repository for low- and medium-level waste, the research program and a transportation system as well as decomissioning of all plants. The National Board for Spent Fuel administers the

financing system. The fee is paid into funds, one for each utility, at the Bank of Sweden.

The fee for year 1986 as well as for 1987 is about 3 mills/kWh. About 40% of the fee should cover final disposal of spent fuel. That means that the fee for this part of the program is of the same magnitude as your cost in the United States. The rest of our fee should cover the cost for transportation, interim storage, research and decommissioning.

The Swedish debate and parliamentary decisions have contributed to the fact that Sweden today has a fairly complete system for the back-end of the nuclear fuel cycle also with regard to legal, financial and administrative aspects. The work done so far has demonstrated that all nuclear back-end activities can be technically managed in a safe and satisfactory way.

The implementation of the waste management system will not be possible, unless it is accepted and supported by the public. Information to the public concerning the safety of the systems is an essential part of the waste management programme. The most crucial issue at present is the decision on sites for detailed investigations. No efforts is saved to promote the acceptance of our nuclear waste management programme to the Swedish public. However much remains to be done to gain public acceptance. We have met quite strong local opposition at several of our test sites. On the other hand we have succeeded in finding sites for CLAB and SFR and test sites in the vicinity of the nuclear power plants. These sites are better accepted than those elsewhere of many reasons. People living in communes with nuclear power stations accept nuclear power better than people living far away.

Broad and open international cooperation is essential in solving the problems with radioactive waste disposal. By

such cooperation we should all be able to find the safest and most efficient methods for disposal. It's also an important way of gaining public understanding and acceptance which is necessary for all countries.

Sweden cooperates with other countries within the frame-work of international organizations such as the IAEA and the NEA of OECD. We participate in and support the work of these organizations. Sweden also works together with several countries on a bilateral basis.

In this context we have had the pleasure of a long time cooperation with the USA and its Department of Energy. The cooperation include work in R&D field as well as exchange of information. From the Swedish side we have found this very valuable and are looking forward to continue the cooperation with your experts.

Briefing on Swedish Nuclear Waste Programme for the US Congress Committees

Dr. S Bjurström, President SKB

In Sweden we do - in principle - have three kinds of radioactive residues. We have spent nuclear fuel and various kinds of low- and medium-level reactor waste. In addition, decommissioning waste will be generated in the future, when old reactors are to be decommissioned and dismantled.

The total amount of spent fuel - up till 2010 - is estimated to around 7,800 tonnes, only 1/10 of the planned capacity for one repository in the US.

The basic principle behind the Swedish strategy of radioactive waste management is that short-lived waste (<500 years) should be deposited directly without interim storage, whereas for spent fuel and other long-lived wastes, an interim storage of 30-40 years is foreseen prior to final direct disposal in crystalline rock formations.

This "once-through" strategy has been judged to be the most rational and cost effective solution in Sweden under the prevailing conditions. It is also, at present, the politically preferred option.

On the other hand, the fairly long period of time that is assumed for interim storage of spent fuel provides freedom of choice between various management options up to the year 2000, when a final decision should be taken.

Essential parts of our waste management system are already in operation or are under construction. The system is illustrated in fig. 1. The central interim storage facility for spent nuclear fuel, CLAB, and the transportation system are both in operation. The final repository for low and medium level operational reactor waste, SFR, is under construction and will be put in operation 1988. Remaining parts for which decisions have not yet been taken are a conditioning and encapsulation plant for spent fuel and a final repository for

long-lived waste. The construction of facilities will not start before 2010, according to present-day plans. Extensive R&D work is being conducted for these parts of the system aimed at finding an optimum solution in relation to design and site.

FINAL DISPOSAL OF LOW AND MEDIUM LEVEL WASTE

Both the reactors and the intermediate storage facility will produce operational waste with a relatively short life such as ion exchange resins, filter materials from water cleaning systems; or ashes from inceneration of combustible waste. Concrete and bitumen are used for solidification.
The waste from the operation of the reactors has to be isolated for up to some hundred years. Some very low-level waste will be disposed of by shallow land burial at the reactor sites.

The operational waste is at present stored at the reactor sites but will from 1988 onwards be transported to the central facility for the final disposal near the Forsmark nuclear power plant north of Stockholm.

The entire repository is situated in rock 50 m below the seabed about 1 km outside the Forsmark harbour, fig. 7. The repository consists of rock caverns of various designs depending on the type of waste to be disposed of. The medium-level waste which contains most of the activity will be deposited in a concrete silo structure cast inside cylindrical rock caverns and the waste will be isolated from the surroundings by concrete walls and a layer of clay backfill between the silo and the rock. The low-level waste will be deposited without extra barriers in rock caverns, designed for the particular kind of containers being used for the waste. When the repository is filled the entrance tunnels will be plugged with concrete to seal the caverns. After sealing of the repository, no further surveillance will be needed.

The location of the SFR below the seabed is advantageous from the point of safety. Under the horizontal seawater table the driving forces of the ground water flow in the fissures of the rock are almost eliminated and the water is almost stagnant around the repository. Another advantage is that one will not have to monitor the facility for a couple of hundred years.

The environmental impact of the SFR has been calculated. The conservatively calculated dose to the most exposed individual is less than 3 millions of a Sv, a factor of 500 less than natural radiation. The actual dose will most likely be much lower.

The Swedish solution for low- and medium-level waste has been looked on as being ambitious. In Sweden with favourable possibilities for constructions in rock caverns are an obvious alternative which could be accepted as well by the public as by the authorities.

The total construction costs of the facility will be around 150 million USD. These figures correspond to a storage cost of 1500 USD per stored m^3. Per kWh the cost for low- and medium-level waste is low, just 0.15 mil/kWh.

HIGH LEVEL WASTE ...

The most important and crucial part of waste management systems are the handling and disposal of the spent fuel.

The main features of the Swedish once-through scheme for direct disposal are briefly as follows:

After discharge of the reactor, the spent nuclear fuel is stored in the nuclear power plant storage pools for at least a six-month period. The fuel is then transported to the central interim storage facility for spent fuel. In this storage the fuel will be stored for a period of 30-40 years and thereafter transported for encapsulation and final storage deep down in the Swedish bedrock.

INTERIM STORAGE ...

Since 1985 a central facility for interim storage of spent fuel from all Swedish reactors is in operation, CLAB, (fig. 8). At the time when the facility was designed, the end of the 70ies, wet storage was the only method that had been applied on a large scale. Dry storage was at that time not considered a proven technology and could not be used and still achieve start-up of the operation of CLAB in 1985 which was highly desirable in order to avoid problems with shortage of storage space at some nuclear power plants.

A central interim storage facility was proposed already in the mid 1970ies, as the most needed waste management facility in Sweden, by a government appointed parliamentary committee.

The main reason for the decision on an interim storage policy for spent fuel are

- offer flexibility in the development of an optimum final disposal system

- makes the final disposal easier and possibly also more economic

- site selection for the final repository needs time and a central storage is more rational and safe than expanding local facilities.

The underground storage facility is situated on the east coast of Sweden adjacent to the Oskarshamn power plant.

The rock cover provides good protection of the stored fuel against any impact from the outside such as acts of war and sabotage. The storage capacity is 3,000 metric tonnes and will cover Swedish needs up to at least the mid of the 1990s. An extension will then be required to accommodate all the spent fuel and core components emanating from Swedish reactors. This extension can be performed by excavating additional rock caverns parallel to the first one.

The central facility has now been in operation for 1.5 year and our experience is very good. More than 400 tonnes of fuel have been received and stored.

The investment in the central storage facility has been 250 million USD in 1986 money and annual operating costs are about 10 million USD. The total corresponds to a cost per kWh is less than 0.5 mil (US).

FINAL DISPOSAL ...

For final disposal of the high-level waste present planning forsees a start of the construction of a repository around 2010 in order to have it ready for operation around 2020.

The decision on "how and where" Sweden finally will dispose of its high-level waste will be taken by Government and Parliament around year 2000. According to law, the decision should be based on comprehensive research and development programme covering possible alternatives.

Extensive research has been conducted since the mid-70s. It has resulted in concepts for final disposal of waste from reprocessed fuel (KBS-1) as well as for direct disposal of spent fuel without reprocessing (KBS-3). These concepts have been accepted as safe by the government as fulfilling the requirements of the law.

The concept for direct disposal of spent fuel in crystalline rock - KBS-3 - was presented to the

Government in 1983 and was approved after extensive review by the Swedish authorities and by experts in Sweden and around the world.

In principle, final disposal according to KBS-3 is technically fairly simple; the spent nuclear fuel is encapsulated in thick copper canisters that are deposited 500 m down the crystalline bedrock, figure 9.

The safety of the repository is based on the fact that the degradation of the canisters and subsequent transport of the radioactive substances will take such a long time that the radioactive substances will decay and be diluted to such a degree that they reach the biosphere only in harmless quantities. The waste is isolated from the environment by a number of mutually redundant barriers such as the rock mass, a bentonite buffer, highly corrosion resistant, copper canisters, and not least a very low solubility of the spent fuel.

FUTURE RESEARCH ...

The purpose of future research work is to develope a disposal system that fulfils the requirements ofsafety and is optimized from a technical and economic point of view.

The study of alternatives is thus in the interest of the utilities, as well as being required by the State.

Our overall timetable and main research areas are indicated on fig. 10.

The future work comprises:

- continued R&D work in order to further deepen the scientific knowledge
- studies of alternatives to methods and concepts investigated so far
- optimization of systems in terms of technology, economy, localization etc. in view of improved scientific base
- investigations for site selection.

The research work is aimed at obtaining the necessary base for a site specific siting application for a final repository for high-level spent nuclear fuel around the year 2000; choice os system is planned for the mid 1990s and choice of site for 1998.

SITE SELECTION

Investigations on various scales, including extensive drilling at 8 sites, have confirmed that the Swedish bedrock, dominated by stable old age granites and gneiss formations, provides - from a geological point of view - appropriate and safe opportunities at many places for the siting of a repository.

The future site selection procedure has to consider as well technical and legal aspects as public acceptance and political views. The technical aspects are perhaps easiest to plan but they will interact with the others. The following stages are planned.

1. 1987-1990. Supplementary non-site specific geological investigastions aiming at deeper understanding of such phenomena as ground water movements and bedrock stability. Development of methods for detailed site investigations.

2. 1990-1992. Evaluation of existing site specific data. Supplementary geological site specific investigations on interesting sites. Selection of two sites for detailed characterization.

3. 1993-1998. Detailed characterization sites. Includes shaft sinking.

4. 1998-2000. Selection of final repository site and siting application.

LEGAL AND ADMINISTRATIVE ASPECTS, PUBLIC ACCEPTANCE

The Swedish legislation regulating the licensing procedure is different from the one in USA.It is less detailed. There is in principle no need for any formal approval from authorities or Government for the preconstruction works of a repository. For the investigations only permission by the landowner is needed.

However, before any real construction could start the applicant must obtain a series of permits according to various laws.

First, and perhaps most important, the applicant must obtain approval from the Government for a siting permit under the Building Act. The municipal council has the right to veto the land use.

After a site permit has been obtained the applicant applies for permits under the Act on Nuclear Activities. The Radiation Protection Act and the Environmental Protection Law. The latter involves a public hearing process. In the end, the Government will issue the

final decision.

The Government considers to alter the existing procedure for site selection in order to involve interested parties earlier. The legal procedure is normally followed and influenced by outside groups. Debates, demonstrations and lobbying sometimes have considerable influence on decisions.

PUBLIC ACCEPTANCE ...

Regarding public attitudes it is well known that Sweden has a big and vital anti-nuclear debate for many years.

In this context radioactive waste matters have early been in the focus of the discussion. During recent years the number of people that are confident about safe radioactive waste disposal has increased somewhat. We are possibly in a better position than many other countries. Before Chernobyl many felt that the waste issue was the only remaining reason not to go on with nuclear power in Sweden.

Yet, polls show that a large fraction of the Swedes - around 50% - do not believe we have a satisfactory solution to our waste problems.

On the other hand, most people admit that they are not well informed and a majority thinks it is important to support the striving for solutions.

In spite of these facts it has in practice been possible to go on with geological investigations, construction and operation as planned. Our early start to develop various systems has been an obvious advantage as well as the localization to areas with nuclear power plants, where people are better informed.

As mentioned above the most crucial part of our work, and of different character, is the investigations for sites. We have - as in most countries - a NIMBY syndrome also in Sweden - and we have local oppositions from aggressive groups around the country. On the other hand, very few local municipal boards are officially against. There exists probably a kind of consensus that if an area, after very thorough investigations is judged to be the best one, the community would accept.

The view that the work so far has demonstrated that the whole backend can be technically managed in a safe and satisfactory way is thus still not sufficiently shared and accepted by the public.

Our strategy to improve public acceptance and confidence is to openly present results from research,

8

investigations and operations to demonstrate the capacity and competence of our system to maintain a high level of safety.
If and when this will work remains to be seen.

* - * - * - * - * - *

Stockholm, 16 January 1987

SWEDEN IN EUROPE

Figure 1

ENERGY DATA
SWEDEN AND USA 1985

	SWEDEN	UNITED STATES
POPULATION (mill.)	8.4	239
ENERGY SUPPLY (PJ)	2300	77100
ELECTRICITY PRODUCTION (TWh)	132	2470
Hydro	70	285
Nuclear	56	385
Solid fuels	3	1400
Oil	3	100
Gas, others	–	300
SHARE OF ELECTRICITY IN TOTAL FINAL ENERGY CONSUMPTION (%)	30	14.5
ELECTRICITY CONSUMPTION PER CAPITA (kWh)	14300	10500

Figure 2

Nuclear Power Facilities in Sweden (Total capacity 9500 MW)

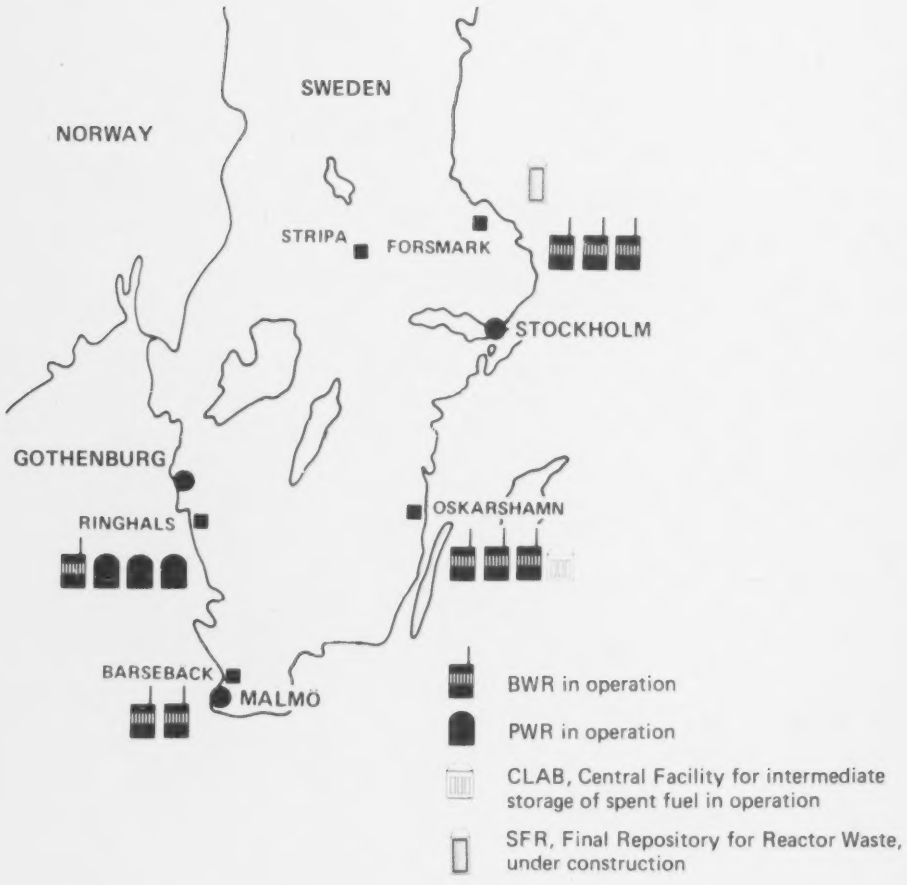


Figure 3

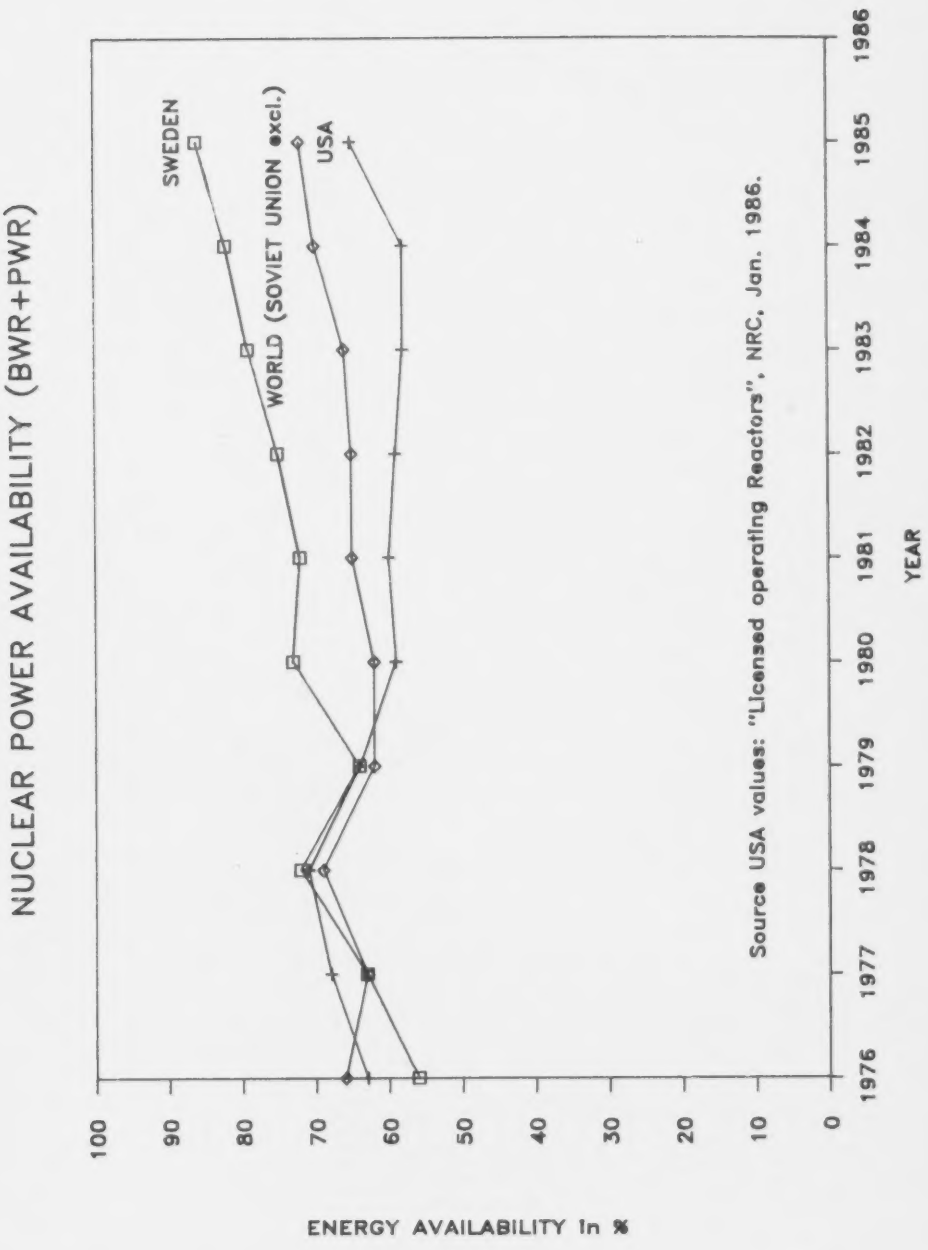

NUCLEAR POWER AVAILABILITY (BWR+PWR)
SWEDEN
WORLD (SOVIET UNION excl.)
USA
Source USA values: "Licensed operating Reactors", NRC, Jan. 1986.
ENERGY AVAILABILITY In %
YEAR
100
90
80
70
60
50
40
30
20
10
0
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986

Figure 4

SWEDISH NUCLEAR WASTE MANAGEMENT AUTHORITIES
MINISTRY OF ENVIRONMENT AND ENERGY
SWEDISH NUCLEAR POWER INSPECTORATE (SKI)
NATIONAL INSTITUTE OF RADIATION PROTECTION (SSI)
NATIONAL BOARD FOR SPENT NUCLEAR FUEL (SKN)
NUCLEAR POWER UTILITIES
SWEDISH STATE POWER BOARD - RINGHALS
FKA - FORSMARK
SOUTH SWEDEN POWER SUPPLY - BARSEBÄCK
OKG - OSKARSHAMN
SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT Co (SKB)

Figure 5

Swedish Nuclear Waste Management System

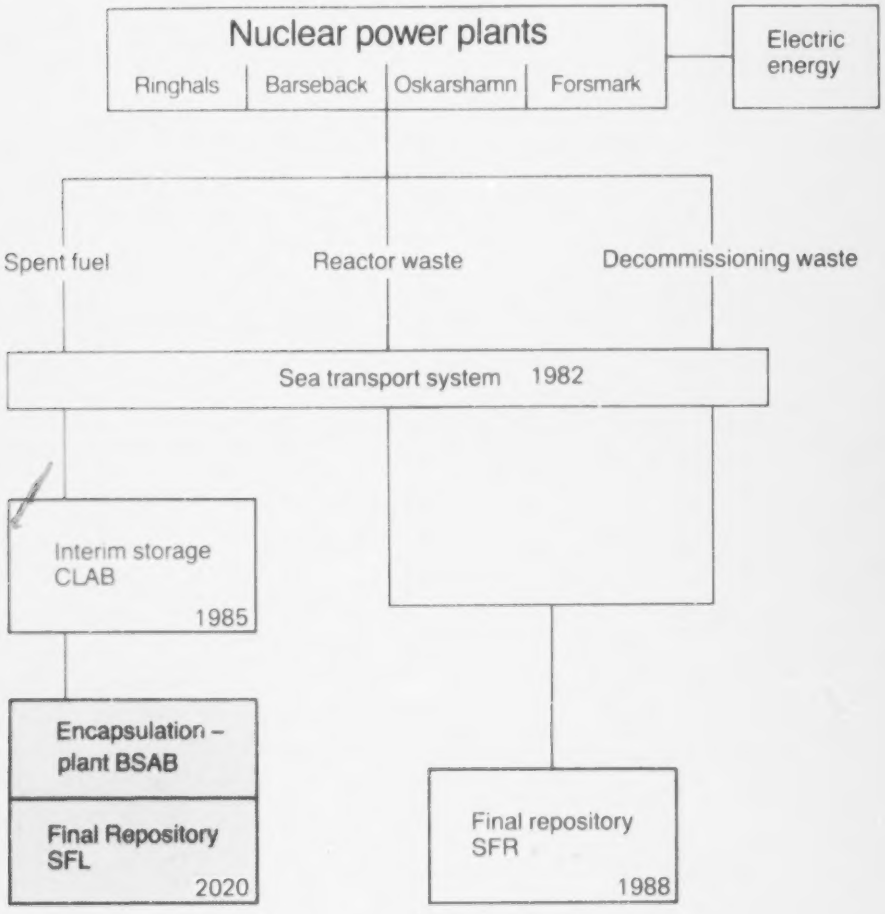


Figure 6

Repository for final disposal of low-and medium level reactor waste - SFR

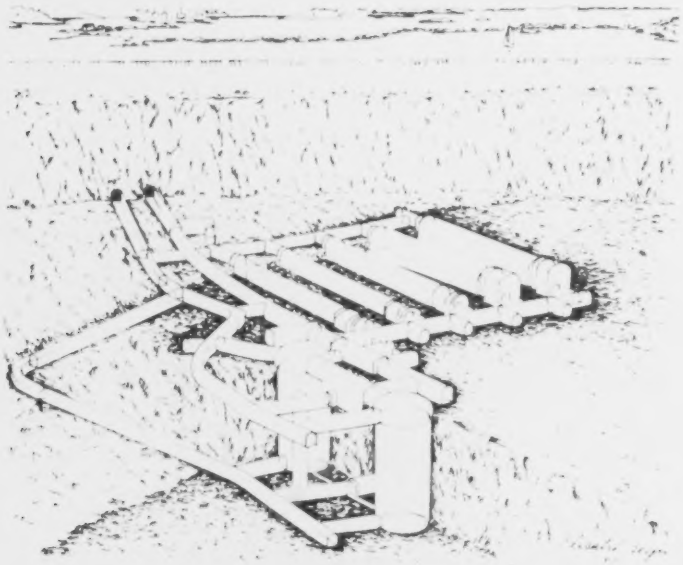
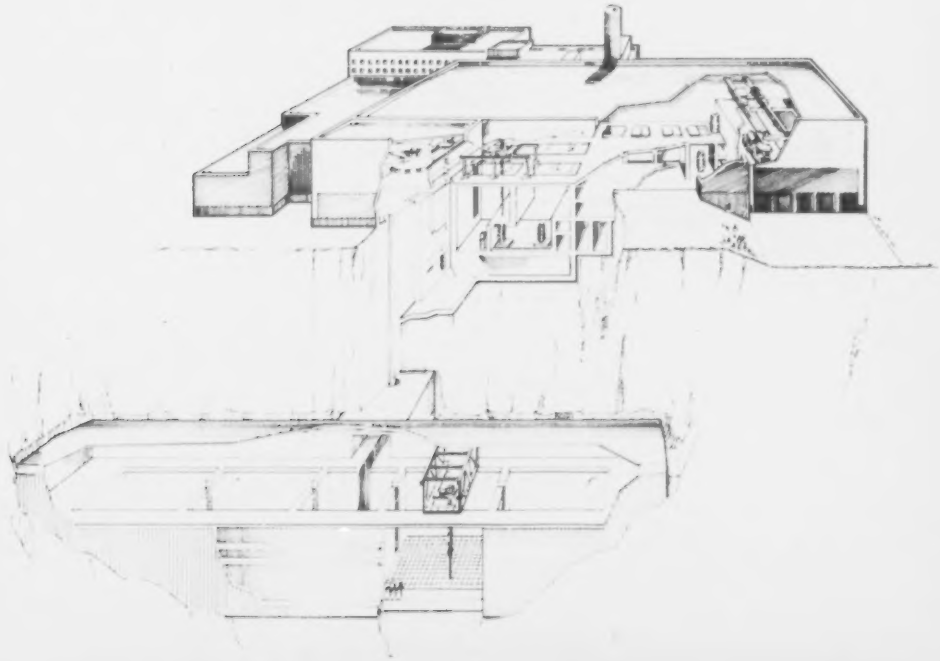


Figure 7

Central interim storage facility for spent nuclear fuel - CLAB



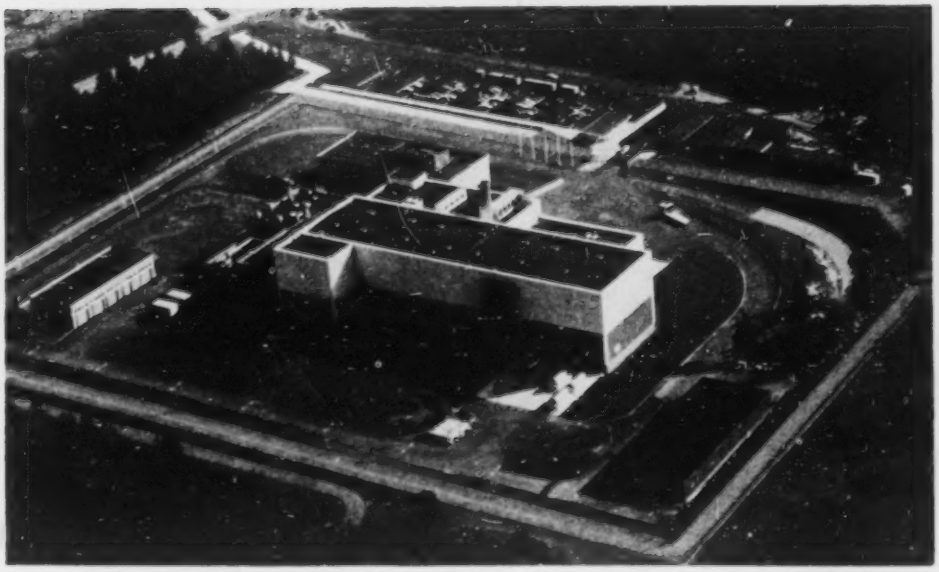


Figure 8

The KBS-3 Concept for Direct Final Disposal of Spent Fuel

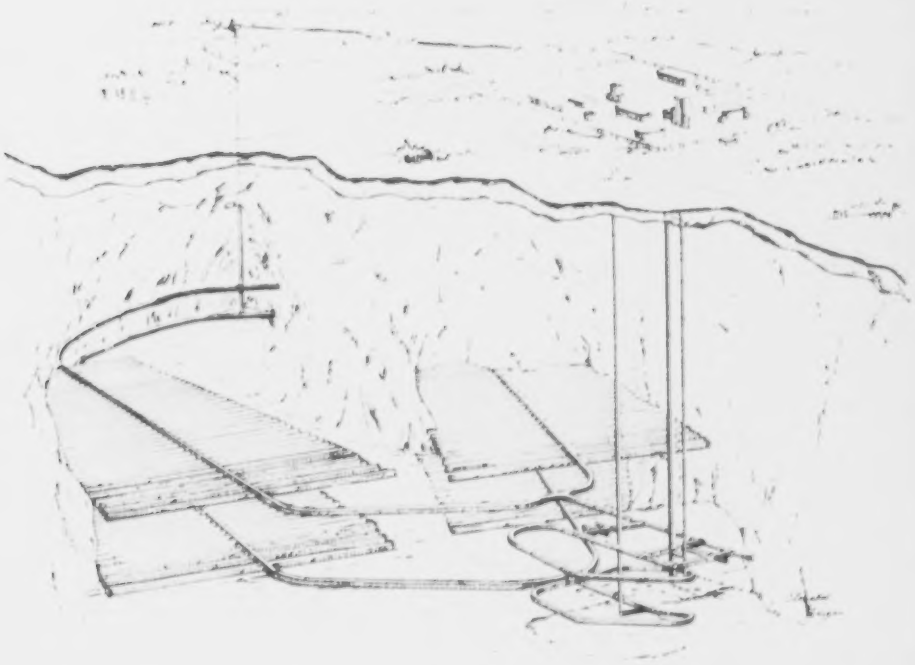


Figure 9

Time table for SKB research program

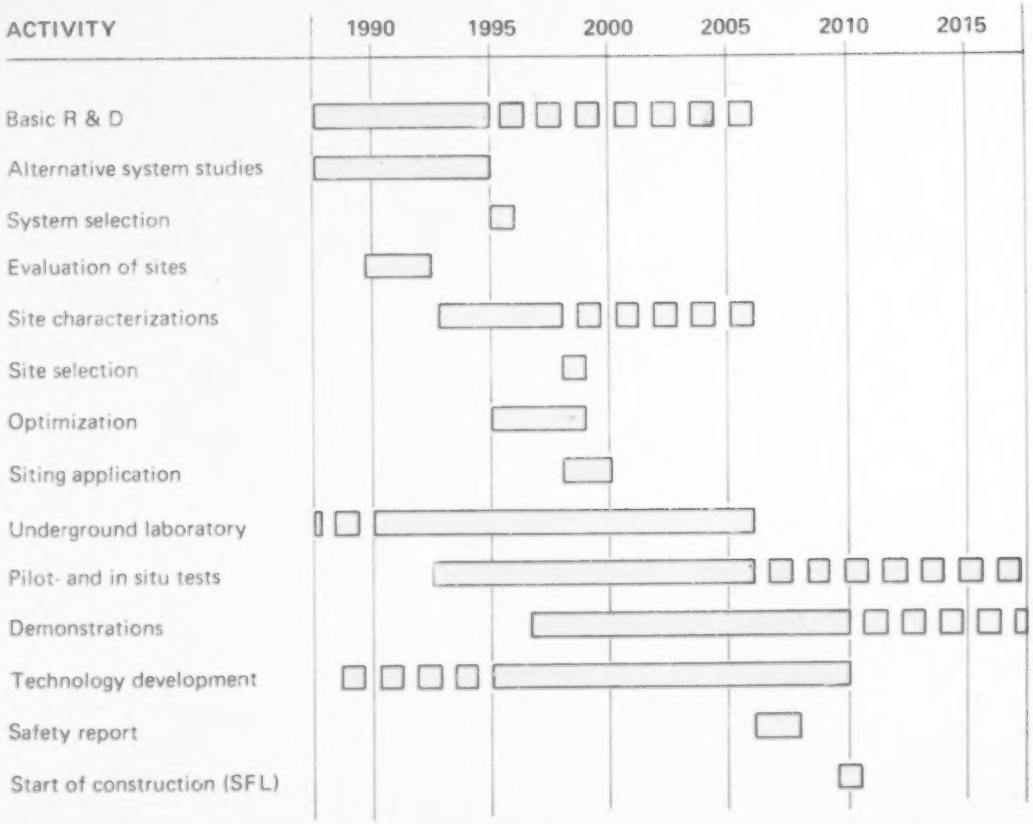


Figure 10

The CHAIRMAN. Thank you very much indeed, Mr. Nyquist.
Dr. Bjurstrom.

STATEMENT OF DR. STEN BJURSTROM, PRESIDENT, SKB

Dr. BJURSTROM. Thank you very much, Mr. Chairman.

First I would like to say as Chief Executive of SKB, I appreciate very much to meet with you today and to have this opportunity to inform you about how we are handling disposal of our radioactive residues in our country.

As we have already touched upon, in Sweden we have as you may know a quite simple system. We have three kinds of radioactive residues. We have, as you know, the spent nuclear fuel with the high activity to start with and the long life; and then we have various kinds of medium- and low-level reactor waste from the operation. Then we also have to consider in the future, perhaps even earlier than we thought, decommissioning waste from the decommissioning and dismantling of the old reactors.

It is very important to see that we have a small system in Sweden compared to the United States. As I say, if we compare the amount of spent fuel, it is around 7,800 tons, if all the 12 reactors are operated up to the year 2010 in December. It means it is one-tenth of the repository you are talking about here in the United States, one of the first ones.

We have a simple, basic principle behind the Swedish strategy for the management of radioactive waste. That is, short-lived waste should be disposed of directly without interim storage in a central facility; and, as we said, the spent fuel should be stored in an interim storage for 30, 40 years, and then to the final disposal.

The CHAIRMAN. Now your interim storage is done at one storage site, or a number?

Dr. BJURSTROM. It is just one storage site that should be expanded. Today it has a capacity of 3,000 tons, and it will be expanded up to the 8,000 tons.

The CHAIRMAN. And that is in operation today?

Dr. BJURSTROM. It is in operation since the summer of 1985.

The CHAIRMAN. Now did you plan to describe that in detail?

Dr. BJURSTROM. Yes, I am coming to that. I can make it a little shorter.

As I said, the system consists of four parts, as you may see on this figure 6. It is a very simple system. Three parts are already in operation, or are in the late stage of construction. You can see the interim storage CLAB. It has been in operation since 1985. We have a sea transportation system. We have a transportation system, and it has been in operation since 1982, and we have the final repository. There is the final repository for the low- and medium-level waste, and we plan to have it in operation next year.

Then we have the remaining part for which a decision has not yet been taken, and that will be conditioning and encapsulation plant for the spent nuclear fuel, and a final repository for long-lived waste. Here we have the time that the construction will start around 2010, and then it should be ready for operation in 2020. For this, as has been mentioned, we have an extensive R&D work going on.

Just to touch on the low- and medium-level repository, if you look on figure 7 you can see it is situated in rock 50 meters below the seabed, and it consists of rock caverns of various designs depending on the type of waste to be disposed of. The environmental impact has been calculated for this kind, and it is very low. The most exposed individuals would be exposed to a dose that is 3 microSv, a factor of 500 to 1,000 less than the natural radiation in the area.

The Swedish solution for the low- and medium-level waste has been looked on as being very ambitious from other countries in Europe, but it is a very obvious solution. In Sweden we have a tradition in using the underground and the rock, and this is an alternative that could be easier accepted as well by the public as by the authorities. We were short of time.

It costs for 150 cubic meters around $150 million U.S., and per kilowatt hour 0.15 mil.

If you look at the high-level waste, which is an important and crucial part of the waste management system, here the spent fuel is being stored at the reactor sites for a period of 6 months up to 1 year, and then all of it will be transported from the four sites to the central interim storage.

The CHAIRMAN. Those are in pools of water?

Dr. BJURSTROM. Pardon?

The CHAIRMAN. The first storage at the reactor site is in water, in swimming pools, as we call them?

Dr. BJURSTROM. In pools, yes. But they have a capacity for 5 years of production, so they have to be emptied.

As we have already touched on, we have a central facility and it has been in operation since 1985, and we have the wet storage in pools. I would like to mention that why do we not have a dry storage, but then you must remember that it was designed in 1978. The construction started in 1980. At that time, wet storage was an established technology which could be licensed in a shorter time, and dry storage was very immature at that time.

I do not know what we would have chosen today, but we are satisfied with the wet storage system we have chosen. As we mentioned, it will be extended. We are thinking of rod consolidation and so on, but as we have all the reception building there already, it would probably be that we lost another cavern for that. We have it underground. This is, as you know, a tradition in Sweden to use underground for storage. We have a couple of hundred underground oil storage. It is well covered. But of course in the price by doing that, we have also a good protection from impact from outside also in case of war and so on.

We have spent around $250 million U.S. in 1986 money on that facility, and it costs us around $10 million U.S. per year to operate. This corresponds to a cost per kilowatt hour in Sweden of 0.5 mil, or something like that, for the interim storage, as well capital cost, as operation.

If we go on to final storage, we plan to have construction started around 2010 in order to have it ready for operation in 2020. This decision on how and where will be taken by the Government, and probably the Parliament, around the turn of the century. According to law, we have in the Nuclear Act, the decision should be

based on the results of comprehensive research and development work covering various possible alternatives.

As has already been mentioned, we have a very good start for that. We have a safe method already approved by the Government. We call it KBS-3, and it is quite well known. The spent nuclear fuel is in this method encapsulated in thick copper canisters that are deposited in 500-meter deep down in the crystalline rock in Sweden.

The CHAIRMAN. Now this is the CLAB?

Dr. BJURSTROM. No, this is what we call SFL, which is the final repository.

The CHAIRMAN. Now on the CLAB, would you——

Dr. BJURSTROM. This is interim storage. We call it CLAB, C-L-A-B.

The CHAIRMAN. And you do not have those encapsulated?

Dr. BJURSTROM. No. We have just the fuel—pardon? Oh, yes. No, no. It is a conceptual study, the KBS-3, and it was stipulated in the law in order to fuel the two last reactors in Sweden.

The CHAIRMAN. Well, now, I see your figure 8 here which shows your interim storage facility, and those look like the swimming pools, and that lasts for just a matter of months.

Dr. BJURSTROM. No, no. That is our interim storage where we store the fuel for up to 40 years.

The CHAIRMAN. Up to 40 years in the swimming pools?

Dr. BJURSTROM. Yes.

Mr. AHAGEN. Underground, at the one site.

Mr. NYQUIST. Underground in Sweden. We take the spent fuel from the power stations, bringing them to the CLAB, and they will be stored there for up to 40 years.

The CHAIRMAN. I see. And you foresee—and those are just your fuel rods as they come out of the reactor?

Mr. NYQUIST. Yes.

The CHAIRMAN. Is there any problem with leakage or fracturing of the surface of the fuel container?

Mr. AHLSTROM. No, we haven't had any problems with the wet storage of fuel rods, and it has been practiced around the world for decades now. I think there are fuel rods here in the United States that have been stored under the water since the late 1950's without showing any degradation of the cladding. So we are confident that we can meet these 40-year interim storage period that we are planning, but we are continuously monitoring the experience in all countries.

The only thing you have to do is you have to have maintenance, and you have to have control of the water chemistry in the pools where you store the fuel, and then it will be no problem.

The CHAIRMAN. Now the water becomes highly radioactive, does it not? Or does it?

Mr. AHLSTROM. No. There are no neutrons, so it will not be activated. There will be some corrosion products that will be dissolved in the water, so you have to have a cleaning system on the water in the pools so you get some activated, ion-exchange resins and things like that, like the medium-level waste you get from the reactors, but as the short-lived products have decayed, it will be very

low activity compared to the similar waste that you get from a power plant.

The CHAIRMAN. Do you calculate what the limit of storage in the pools would be? Let's say you did not have, for one reason or another, did not have your final storage facility available. Do you know how long you could leave them in the pools?

Dr. BJURSTROM. We have assessed that it would probably not be a problem to have them stay there for another 30 or 40 years after the 40-year period, but we will gain experience as time goes. No one has done that yet, but there have been rods for 25 years at least in water without degradation. There is no reason why it should not stay for 50 years.

Mr. NYQUIST. But as mentioned earlier, we do not see any reason to store it more than 40 or 50 years, and we would like to have the final repository.

The CHAIRMAN. I understand.

Dr. BJURSTROM. May I proceed?

The CHAIRMAN. Yes, please.

Dr. BJURSTROM. Well, perhaps a few words about site selection. You asked about the situation today, and from 76 investigations on various scales including drilling have confirmed that the Swedish bedrock, we have an old, stable granites and gneiss formations of the same type you will find in Canada. Those formations provide, from a geological point of view, possibilities for safe siting at many places in Sweden.

From 1993 on there will be a detailed characterization of two or three sites, including shaft sinking, before a final decision on the site is made around 1998. We must have all the materials for decision available around the turn of the century.

This is the site information we have today available. We have also said that we should mention something about the legal and administrative aspects and public acceptance aspects on our program.

The Swedish legislation regulating the licensing procedure is different from yours in the United States. In that way, it is less detailed. In principle, we need few formal approvals from authorities of Government before the actual start of construction, formal ones. For land investigation, for instance, we only formally need the permission of the landowner.

However, before the actual construction work could start, we must obtain a series of permits according to various laws.

First, and perhaps most important here, is the siting permit under the Building Act. An applicant must obtain approval from the Government, which consults, among others, the local municipal council. The municipal council has the right to veto the land use. So they could stop it.

After siting permits have been obtained, the applicant applies for permits under the Act on Nuclear Activities, the Radiation Protection Act, and the Environmental Protection Acts. The latter involves a public hearing process—not exactly what you have here, but it is public. In the end, the Government will issue the final decision.

These limit demands in the law might give you the idea that the public is not involved in the investigations and planning phase. The active situation is different. There is no way of progressing

without the massive information of interaction with groups concerned, and this formal procedure is followed and influenced by outside groups through debates, demonstrations, occupations, media, lobbying, et cetera, sometimes with considerable influence of the decision.

We have this on the local level, and we have it on the governmental level. So we have to deal with the same kind of problems you can have here. Presently the government is considering altering the procedure for site selection in order to formalize the involvement of interested parties earlier.

Perhaps I could end my presentation with a few words about public opinion in Sweden about the waste disposal issue. As had been mentioned, it is well known that we have had an intense antinuclear debate in Sweden for many years, and in this context radioactive waste disposal methods have early been a focus of discussion.

The number of people being confident about the radioactive waste solution has increased somewhat in Sweden during recent years. We are possibly in a better position than most other countries. Yet, polls show that the large fraction of Swedes, around 50 percent, do not believe that we have a satisfactory solution to our waste problem. In spite of this fact, it has been in practice possible to go on with the geological investigations, constructions, and operation of facilities as planned.

Our early start to develop various systems has been an obvious advantage, as well as a localization of facilities to areas with nuclear powerplants where people are better informed, as has been mentioned. And as already mentioned, the most crucial part of our work and of different character is the investigation for the site.

We have, as in most countries in Europe and here, a well-developed "not-in-my-backyard" syndrome also in Sweden, and we have local opposition from aggressive groups around the country. We have, on the other hand, very few local municipal boards who are officially against. There exists probably a kind of concensus that if an area after thorough investigation is judged to be the best one, the community should accept.

Our strategy to improve public acceptance and confidence is to openly present results from research investigations and operations. Here we think it is very important to be concrete, and we use our built facilities as well as our research facilities for demonstration of the techniques.

The CHAIRMAN. Do you have any incentives for the local area to take the facility?

Dr. BJURSTROM. Pardon?

The CHAIRMAN. Do you have any incentives, any tax forgiveness or jobs, or whatever?

Dr. BJURSTROM. We have the incentive of creating jobs. That is the only incentive we offer.

Mr. NYQUIST. Well, the municipalities are well aware of that. That is why especially municipalities around the nuclear power stations are in favor of taking care of the waste.

The CHAIRMAN. I was just looking at you—Senator Hecht is from Nevada, which is a potential site, and I just was making sure he heard that about jobs. [Laughter.]

Dr. BJURSTROM. But as I said, we do not know what will happen in the future when we are narrowing our site selection procedure. We think we will meet quite a lot of resistance, and we certainly have no patent solutions of how to deal with the public acceptance in this field. But up to now, we have been successful.

Thank you very much.

The CHAIRMAN. Gentlemen, thank you very much.

Before I recognize Senator Hecht, I have got to go to another meeting. I want to tell you how grateful we are for your coming here. You may not have all the answers, as you say, Dr. Bjurstrom, but you seem to have a lot more of those answers than we do in this country. You seem to have done a better job of it than we have, and I think a lot of that is in public acceptance. Perhaps the care with which you have proceeded at each step along the way, maybe we have neglected that. I am not sure, but we have a great deal to learn from you, have learned from you today, and hope to commission a trip to see your facilities on the ground, if that is possible.

Before I recognize Senator Hecht, who as I say has more than a passing interest in this subject, when Senator Hecht finishes, if you are willing, Dr. Cooper of our staff would like to ask some questions and, perhaps if you are willing to entertain a few questions from the floor, I am sure some of those in our audience would like to ask some questions if your time permits and if you are willing to do so.

So with that, let me say thank you, again, and recognize Senator Hecht.

Senator HECHT. Thank you, Mr. Chairman.

The record will show that our distinguished chairman wants to take a trip over there to see some facilities, and may I say I would love to accompany you on the trip.

Mr. NYQUIST. We would love to have you both, and all other interested in following our program on the waste management. We would be happy to see you there.

The CHAIRMAN. I have already asked the staff to begin inquiries and planning on that.

Senator HECHT. I do not think you will have any problem with the staff, because I think they are all packed. [Laughter.]

The CHAIRMAN. Thank you.

Senator HECHT [presiding]. Thank you, very much.

I address this question to any one of you. Why did you make the decision not to reprocess?

Mr. NYQUIST. Not to reprocess? Well, when we took the last decision on nuclear, we decided to control the process inside the country so we could take care of all the used fuel inside the country, and therefore we went away from reprocessing. From the utilities' point of view, reprocessing as we are going to finish our nuclear program before 2010, it is not economic.

Senator HECHT. No; it is not economic, but you do get rid of a lot of what we call the "hot stuff."

Mr. NYQUIST. The hot stuff, but we still have to take care of it.

Dr. BJURSTROM. Well, when you do not have a long-term program ahead with the price of uranium and plutonium today, there is very little incentive of reprocessing; and we must have a program

in Sweden which you could terminate in a certain time. With direct disposal, you will have the possibility to terminate at the time you want without, what you say, open ends. So from that point of view, direct disposal is very appropriate under the Swedish conditions.

Senator HECHT. Let us forget the economics. If you had your wish, would you reprocess before you put it into this 40-year plan, and so forth?

Mr. NYQUIST. If we wished?

Senator HECHT. Forget the economics of it now; the money is not involved; economics is not involved. Would you think that would be a better way of handling it?

Mr. AHLSTROM. Do you mean from a safety point of view?

Senator HECHT. Safety in storage, and the amount, the mass of it.

Mr. AHLSTROM. Well, our experience is that the high-level waste is perhaps a little bit easier to handle if you solidify it, but if you reprocess it you get a lot of other wastes that contains long-lived radioactive waste material. So on the balance of it, I do not think there is a big advantage from a safety and handling point of view to have reprocessed waste to take care of instead of spent fuel.

The advantage of having spent fuel is that you have all these long-lived isotopes contained in the spent fuel, and that is what you have to treat. So I would say no, we would not reprocess if there was no economic advantage. That is my personal opinion, about it.

Mr. NYQUIST. I would have the same idea.

Senator HECHT. Do you all feel the same?

Dr. BJURSTROM. Yes.

Mr. AHAGEN. Yes.

Dr. BJURSTROM. This is a quite clear and general idea in Sweden.

Senator HECHT. Now how do Germany and France handle it? Do they reprocess?

Dr. BJURSTROM. Yes; they reprocess. They have a very well established system for that, and they will do it with their own facility within their own countries. So this is a little different.

Senator HECHT. Explain the difference, please.

Dr. BJURSTROM. Well, we have to export it to France. We will not build a reprocessing plant within Sweden.

Senator HECHT. Now let's forget about economics.

Dr. BJURSTROM. Well, we will be depending on the reprocessing in other countries, and this was one of the main ideas for developing direct disposal in Sweden, to avoid that situation.

Senator HECHT. Oh, you do not want to send it to other countries to reprocess.

Mr. NYQUIST. We do not want to send away the spent fuel to another country, no.

Senator HECHT. I see. That means you have to bring it back again.

Mr. NYQUIST. Yes.

Dr. BJURSTROM. Yes.

Senator HECHT. Last month I was at Lawrence Livermore Lab in California. Dr. Teller is the senior chairman of Lawrence Livermore Lab, and we were talking about the peaceful uses of nuclear waste products residue in third-world countries where they do not

have ice, or the means of cooling. They can keep fruits and vegetables and meat in a state that you can eat them for several weeks in a very hot climate, because of a certain process known as food irradition.

Have you gone into many peaceful uses for nuclear wastes, such as food irradition that I mentioned?

Dr. BJURSTROM. No; in fact we have not done that at all in Sweden. Also, this radiated foodstuff and so on, people in Sweden and, Sweden as such, are very reluctant to use that, as an official view on it.

Senator HECHT. Official view on it? Because of public opinion?

Dr. BJURSTROM. Mostly that. Not because of scientific reason, and so on.

Senator HECHT. Not scientific at all?

Dr. BJURSTROM. No.

Senator HECHT. So you have that over there, too?

Mr. NYQUIST. Yes.

Dr. BJURSTROM. Yes.

Senator HECHT. Now what type of—I am sure I missed this. What type of storage—I know I heard you say you keep it in water, but do you have salt storage, a granite storage, or what kind of an interim storage facility do you have? What is the makeup of the earth?

Dr. BJURSTROM. It is in water, in pools.

Senator HECHT. In water, all right. Now what surrounds that water? What type of deposit?

Dr. BJURSTROM. It is an underground cavern, and it is around 50 meters below the surface in the granite and the gneiss.

Senator HECHT. It is granite?

Dr. BJURSTROM. Yes.

Senator HECHT. Do you use salt at all?

Dr. BJURSTROM. No; because there is no reason for this. Interim storage could also be a building above ground, if you would like to design it that way; but as we say, in Swedish storage for a long time it is done underground. It is cheap, and at the same time you have got the protection from impact from outside, sabotage and acts of war, or whatever.

Mr. NYQUIST. Senator, I may perhaps say we have no salt caverns at all in Sweden.

Senator HECHT. No salt at all?

Mr. NYQUIST. No salt in the ground of Sweden.

Senator HECHT. Now what type of geology were you going to have on the long-term storage facility that you are going to have finished by 2020? Is that the right date? What type of mineral composition will you have on that?

Dr. BJURSTROM. It will be granite and gneiss, crystalline rock, because that is most——

Senator HECHT. What kind of rock?

Dr. BJURSTROM. Crystalline rock, granite and gneiss, and so on, which Sweden up to 85 percent consists of that. I mean, this is our typical bedrock.

Senator HECHT. Now France uses salt? Is that correct?

Mr. NYQUIST. Yes.

Dr. BJURSTROM. And granite, and clay.

Mr. AHLSTROM. Well, as I know, France has not really decided that. They are looking into various alternatives, salt, clay, granite, basalt, as I know, and they plan to make a decision this year or next year.

Senator HECHT. How is France handling the interim waste right now?

Mr. AHLSTROM. Before they reprocess the waste, they are storing the spent fuel in water pools just like in CLAB or at nuclear powerplants.

Senator HECHT. Just like you are.

Mr. AHLSTROM. Yes. And when they have reprocessed the waste, the high-level waste is transformed into glass, and these glass bodies are stored in dry storage in concrete caverns that are constructed at the site of the reprocessing plant.

Senator HECHT. I was under the impression it was a salt formation. I do not know where I got that.

Mr. AHLSTROM. They are working on selecting the geology for the final repository, but they have not decided yet.

Senator HECHT. Do you take any nuclear waste from any other countries for storage in your facilities?

Dr. BJURSTROM. No. This is an official view that every country should control their own waste and solve their own problem. We will receive 24 tons of waste from Germany, but this is an exchange, and they will take some fuel from us that we had in France, and it is a way of cleaning up an old reprocessing contract. But this is just for once.

Mr. NYQUIST. This is from the first stage of our nuclear program when we decided upon reprocessing, but now when we have turned away from the reprocessing we must also get rid of the spent fuel we had down in France when we had made the change.

Senator HECHT. Do you intend to explore the best waste disposal technology in sight, or rather a technology that provides reasonably adequate protection to the public and the environment?

Dr. BJURSTROM. Of course.

Mr. NYQUIST. Would you repeat the question, please?

Senator HECHT. Basically, do you intend to use the best technology, forgetting economics and public opinion?

Mr. NYQUIST. We are always heading for the best technology, even if it would cost more, that is right.

Senator HECHT. This is not a scientific question.

How have you successfully handled the public opinion issue?

Mr. NYQUIST. Well, as we told it, you must be very open. You must inform about everything about what you have learned about your studies and research, and hopefully convince people that you have a safe method. We are convinced that we have a safe method.

But as Mr. Bjurstrom said, we have not gained the public for that opinion yet. I think in the years to come that we must—that international cooperation could help us, all countries with these questions could help us just to create a basic idea about what is safe. I think every country has problems to explain what they do inside their own country. So a way of interchanging ideas on that matter will be helpful for all of us.

Senator HECHT. How do you handle your transportation to and from your storage site?

Dr. BJURSTROM. Well, we have all the nuclear power stations situated along the coast, and it is very natural to have a seabound transportation system. We have specially built ships and casks so all radioactive residues in Sweden will be transported on sea.

Senator HECHT. On the sea?

Dr. BJURSTROM. On the sea.

Mr. NYQUIST. On the sea, along the coast.

Dr. BJURSTROM. Of course we can use land transport, but there is no advantage with that. It is heavy transport, and it is very natural to use sea transport for that.

Senator HECHT. That is interesting.

Do your local governments have any veto power over the site of the final repository?

Dr. BJURSTROM. Yes.

Mr. NYQUIST. Yes.

Senator HECHT. Then what does your Government do if the local community does not want it?

Dr. BJURSTROM. We have to leave the place.

Mr. NYQUIST. We leave the place, yes, or discuss it.

Senator HECHT. Do you anticipate this?

Mr. NYQUIST. We have to plan and work with it.

Senator HECHT. So it is a possibility?

Mr. NYQUIST. There is a possibility of a veto, that is right.

Dr. BJURSTROM. But this has been discussed, and there is opinion that among the communities they feel, if after thorough investigation their community would be the most suited for the final disposal, they should accept. And we have not had any official objections about that view, looking on it, yet.

Senator HECHT. How would you compare your container to transport waste against our containers that we use to transport nuclear waste?

Dr. BJURSTROM. Well, I think our containers there are the European Transnuclear Standard, which follow the International Standard. I am not familiar with yours here in the United States, but I think they are a very robust type and they are, as I understand, the same. I mean, they can withstand almost anything mechanical from outside. Is that so?

Mr. AHAGEN. Most of the transportation cask testing is actually performed here in this country, and we rely much upon your testing.

Senator HECHT. Oh, you do?

Mr. AHAGEN. Yes.

Senator HECHT. Thank you for telling me that.

To what extent will you rely on engineered barriers, rather than the geologic medium itself, to ensure that the permanent repository is safe?

Mr. AHLSTROM. We have, as Mr. Bjurstrom said, presented a conceptual design study on the final repository for spent nuclear fuel in the KBS-3 report, and that was based on the principle that we have multiple barriers which supplement and are independent of each other. That means that we have both engineered barriers in the design of the repository, as well as geological barriers.

I think the combination is the thing that you have to rely upon for really ensuring this long-term safety that we are looking for in

the final repository for spent nuclear fuel. You cannot say that one is more important than the other. Both are important, and the combination of them constitutes the safety.

Senator HECHT. How far will the waste have to travel from the reactor to the repository? You are on the sea when you travel?

Mr. NYQUIST. Well, it will be almost the same land-bound as sea-bound. I think it will be about, shall we say, 400 kilometers, 200, 250 miles.

Senator HECHT. I thank you very much. I will pass the microphone, and I will look forward to seeing you very soon. Thank you.

Mr. NYQUIST. You are most welcome.

Dr. COOPER. Okay, I think we will try to go now to the public phase of this meeting. The Swedish delegation has very graciously consented to take questions from the audience, or from any other staff here who have questions they want to ask.

The procedure I propose we use, as long as there are questions to be asked, if you have one I will recognize you, stand up, and say who you are, and where you are from, if you have an affiliation; if you do not, if you are just a member of the audience, that is fine. But we would like you to stand up and say who you are.

So the floor is open to questions now.

Mr. Wight.

Mr. WIGHT. I am Arne Wight from the State of New Hampshire. I have been in the State legislature in the Office of Science and Technology Committee for 10 years, and I am certainly grateful that you are here.

In terms of public information and support, what sort of time frame are you telling your people that they can expect to be protected from the release of radioactivity to the environment? Here we are talking 10,000 years.

Dr. BJURSTROM. Well, we are talking in Sweden about very long time periods, too. As you may know, with this combination of geological and technical barriers, we are talking about longer times in Sweden. Of course we have not defined exactly the time period, but at least we are talking about periods up to 10,000 years. Of course for the short-lived waste, we are talking about a couple of hundred years. But for the long-lived, it is a period of up to 10,000 years. But then again, from the scientific point of view, we have shown that the waste will be isolated for much longer times, up to hundreds of thousands of years, with the technical barriers.

Dr. COOPER. Yes.

Ms. CALLAHAN. My name is Debra Callahan, and I am with Senator Conrad's office.

I was very involved in New England with the public information process. We had a tremendous series of public hearings on this issue. I would like to know, How did you get your country involved in the process of the site selection of the final sites you are looking at? Do people say, not in my back yard? Or do they give you more technological kinds of insights? Has this been useful information for you in the whole site selection process?

Dr. BJURSTROM. Well, this is a very tricky thing. As you said, we must start with the question that we have not narrowed, focused on finding the sites. We have just now in Sweden a kind of moratorium. We have found out that we have several places in Sweden

that could be appropriate for the final repository, and that has been enough for the stipulation in the law for the loading permits.

Now we will collect more data, and in the beginning of 1990 we will start the procedure on narrowing on a couple of sites. Then of course we will really be close to the problem with the final repository.

Regarding the interim storage and the final repository for low- and medium-level waste, this is on the sites for nuclear powerplants. In this area, people are very well informed, and we have not had much of a problem. But of course we have had a lot of information to, as well, the municipal administration as public information very well informed.

For instance, we have in relation to our low- and medium-level repository in our approvals, we must inform the public, the general public on the work and what is going on, and we are doing that in various ways. It means that they have been satisfied, up till now, anyhow.

Ms. CALLAHAN. I have a follow-up question. What would you do if all eight area municipalities said they did not want the site?

Dr. BJURSTROM. They are well investigated areas, just to show that it is possible to find a site in Sweden. When we are going in the process of selecting the two or three sites for detailed characterization, then we will choose among a larger sample, more than eight. We have several places in Sweden that could be thought of.

Mr. NYQUIST. The Secretary of Energy says that to take care of the nuclear waste is a national responsibility. That means that she must discuss with the municipalities at last to find a right location. We must find a solution, anyhow.

Dr. COOPER. I have a question. What measures did you have to take to convince the people who live in the vicinity of the CLAB facility that it would not become the permanent site, by virtue of having the waste never moved from there once it gets there?

Dr. BJURSTROM. Well, it is obvious that the interim storage facility, the CLAB, is not suited for long-time storage. So from that point of view, they know it will not be a final repository. So we know very well in Sweden that it has to be moved from CLAB to some more suited places for the final disposal.

Mr. NYQUIST. It is quite clear it would not be accepted as a final repository.

Dr. COOPER. Under Swedish law.

Mr. NYQUIST. Under Swedish law, correct.

Dr. BJURSTROM. I mean, CLAB is a facility that has to be controlled, and it is impossible to have such a one as a final repository, of course.

Dr. COOPER. Dan?

Mr. BERKOVITZ. Dan Berkovitz from the Committee on Environment and Public Works.

In the United States in our program we are looking at various types of geological media such as crystalline rock, basalt, et cetera. How far have you gone down to the crystalline rock, and what gives you the confidence that the repository can be built in crystalline rock? Do you believe that it may be the best? Or are you looking at it because it is the only one in Sweden, or how did you approach that question?

Mr. AHLSTROM. We have, as both Mr. Nyquist and Dr. Bjurstrom have said, long-time experience from working in hard crystalline rock in Sweden, and that is a very abundant type of rock we have in Sweden. Other types of geology suitable for repository we do not have in Sweden, so our crystalline rock is the only thing we have looked at. We have made extensive investigations on eight sites that convinced us that there are many places where you can find the conditions that we are looking for for a repository for spent nuclear fuel.

Besides that, we have been running this international program in the stripa mine in the granite body where we have developed a technique for underground investigations and testing various methods, and also testing some engineered barriers, and that has given us the confidence that we can build this type of a repository in that type of rock we have available. And for Swedish conditions, we think this is a very good solution.

Where you have other types of geology, you have to find solutions that are suitable for those types of geology.

Dr. BJURSTROM. Well, I mean you must know that in Sweden we have that kind of rock that has been aged over a couple of billion years, up to 3 billion years, and the changes and movements in that rock geologically it takes hundreds of millions of years, and we are talking about 10,000 or 100,000 of years. So from that point of view, it seems to be very relevant to use that material.

Dr. COOPER. How are you going to decide whether you eventually characterize one, or two, or three of these final repository sites? It is quite expensive in the States, anyway. Here we are spending roughly a billion dollars for each characterization. So if you want to do three instead of two, it is an extra billion dollars. How are you going to decide whether to do one, or two, or three?

Dr. BJURSTROM. Well, the main idea today is that we should characterize two. We hope that that will be sufficient. But that will be a discussion between us in the industry and the Government and the authorities what they think is sufficient. They would like to have a broad base for their decision, and it might turn out that we have to do another one, but that one we do not know yet.

Dr. COOPER. So the Government will eventually make the decision, and it will be what they feel is necessary as a basis to make the decision?

Mr. NYQUIST. Well, I think the Government must take a final decision on that. We are doing it step by step, as you see. From the utility side, it is very important that we keep to the timetable we have decided on. We hope also that we also can get the decision on the different issues now during the 1990's.

Dr. COOPER. Are there any other questions? Yes, ma'am.

Ms. WRIGHT. My name is Elizabeth Wright. I am with the Atomic Energy Clearinghouse.

I was wondering why you have chosen to use copper for spent fuel canisters as opposed to taking steel, or some other material?

Mr. AHLSTROM. When we did this KBS study, we were in a kind of a hurry because we had a condition in the law that said we had to come up and describe a method that could be accepted by the scientific community and the Government as a demonstration that there was a safe method to take care of the spent fuel. So we

looked at various materials, and we found that with the chemical conditions we have in the deep granitic rock we have in Sweden, copper is almost a noble metal. It is very stable. It has very, very low corrosion rate in that environment.

So we looked into the possibility of making a copper design, and we were successful in demonstrating the design technique for enclosing the spent fuel in copper canisters. Before we decide finally on what we will actually use, we will also continue to look at various materials and see what are the advantages and disadvantages of other materials.

We know that copper is a material that will work for a very long time in the particular environment we have in the Swedish bedrock.

Dr. COOPER. I might say, if there are members of the press here who would like to ask questions, please do so now, too, as well as other members of the public. Are there other questions?

Mr. CAMERON. What are the advantages in terms of safety and the decrease in both heat and radioactivity for storing waste for 40 years before moving it to a final repository setting, as opposed to 5 years, or 10 years?

Mr. AHLSTROM. In order to be able to keep the temperature down and a reasonable size of the package that you put it in so it is advantageous, we wanted to keep the temperature in the rock surrounding the waste package well below 100°C. If you take 5-year-old fuel and store that at the same size of the package, you would get much higher temperature because the heat that you have after 40 years is less than half what you have after 5 years. So it makes the design easier, or it makes the repository considerably smaller.

Because if you wanted to have the same temperature condition, you would have to have very small packages.

Dr. COOPER. Is there a cost advantage to that?

Mr. AHLSTROM. But also I would add, you have to factor in it, you cannot build the repository tomorrow. You have to really do these investigations to find the conditions in detail on the site you select, and that takes some time. So even if you decided you wanted to do it after 5 years, you have to do these investigations before you really start disposing of the fuel, and that also takes time. So these work together to some extent.

Dr. COOPER. And there is a cost advantage associated with this cooling in advance, as well?

Mr. AHLSTROM. Yes.

Dr. COOPER. I know that is an issue that is debated in our country, as to whether there is any money saved by having interim storage in the system as opposed to not having it. I guess you have decided there is a cost savings associated with it.

Mr. NYQUIST. There is a cost advantage.

Dr. BJURSTROM. You can make the repository much more compact, or the canisters bigger, as was mentioned by Mr. Ahlstrom.

Dr. COOPER. Well, if there are no other questions, thank you very much for this very informative briefing, on behalf of the Senate and the committee. We appreciate you being here.

Mr. NYQUIST. Thank you, also. It has been enjoyable talking with you.

[Whereupon, at 4:09 p.m., the briefing was adjourned.]

APPENDIXES

APPENDIX I

Swedish Code of Statutes 1984:3—Act on Nuclear Activities

Introductory provisions

Section 1 This Act applies to nuclear activities.

For the purposes of this act, nuclear activities mean

1. the construction, possession or operation of a nuclear plant,

2. the acquisition, possession, transfer, handling, processing, transport of or other dealings with nuclear material or nuclear waste,

3. the conveyance into Sweden of nuclear material or nuclear waste,

4. the conveyance out of Sweden of
   a. nuclear material or minerals containing such material,
   b. products made from nuclear material or goods containing such material,
   c. equipment or material that has been specially designed or prepared for the processing, use or production of nuclear material or which is otherwise of essential importance to the production of nuclear explosive devices, to the extent prescribed by the Government, and

5. the granting or transfer of a right to manufacture outside Sweden such equipment or such material as is referred to under 4 c and is manufactured within Sweden, to the extent prescribed by the Government.

Section 2 For the purposes of this Act:

1. A nuclear plant means:

   a. any installation for the generation of nuclear energy (nuclear power reactor),
   b. any other installation in which a self-sustaining nuclear reaction can take place, such as a research reactor,
   c. any plant for the extraction, production, handling, processing, intermediate storage or final disposal of nuclear material, and
   d. any plant for the handling, processing, intermediate storage or final disposal of nuclear waste.

2. Nuclear material means:

   a. uranium, plutonium or any other material that is used or can be used for the generation of nuclear energy (nuclear fuel) or any compound containing such material,
   b. thorium or any other substance that is suitable to be converted to nuclear fuel or any compound containing such material, and
   c. spent nuclear fuel that has not been placed in a final repository.

3. Nuclear waste means:

   a. spent nuclear fuel that has been placed in a final repository,
   b. any radioactive material that has been generated in a nuclear plant, or material or any other substance that has become contaminated by radioactivity in such a plant, and
   c. radioactive components of a nuclear plant that is decommissioned.

Basic provisions

Section 3 Nuclear activities shall be conducted in such a manner that the requirements on safety are met and that the obligations that follow from Sweden's agreements for the purpose of preventing the proliferation of nuclear weapons are fulfilled.

Provisions governing radiation protection are laid down in the Radiation Protection Act (1958:110).

Section 4 Safety in nuclear activities shall be maintained by taking the measures necessary to

1. prevent defects in or malfunction of equipment, faulty handling or other action that can lead to a radiological accident, and

2. prevent illicit dealings with nuclear material or nuclear waste.

Licences, permits etc.

Section 5 A licence under this Act is required for nuclear activities. Decisions on licence applications are taken by the Government or the authority designated by the Government.

With regard to nuclear material or nuclear waste in small quantities or with low radioactivity contents, the Government may issue statutory regulations governing permission for everybody, or for a certain occupational group, or for certain establishments, institutions or enterprises to use the material or the waste in teaching or research or for medical, agricultural, industrial or commercial purposes.

Section 6 In addition to a licence under Section 5, a special permit is required for loading a nuclear power reactor for the first time with nuclear material so that a self-sustaining nuclear reaction can take place.

Such a permit is granted only if the reactor possessor

1. has proved that there is a method for the handling and final disposal of spent nuclear fuel and radioactive waste deriving from it which is acceptable with regard to safety and radiation protection, and

2. has presented a programme for the research and development work necessary for ensuring that spent nuclear fuel from the reactor and radioactive waste deriving from it can be handled and finally disposed of in a safe manner.

Section 7 The validity of a licence or a permit can be limited to a certain period of time.

Licencing conditions etc.

Section 8 When a licence is issued, or during the period of validity of a licence, such conditions may be stipulated as are required with regard to safety.

Section 9 With regard to equipment for nuclear activities that is of importance from the viewpoint of safety, the Government or the authority designated by the Government may issue directives concerning testing, monitoring or inspection.

The Government or the authority designated by the Government may also issue directives concerning charges for such testing, monitoring or inspection.

General obligations of licence-holders

Section 10 The holder of a licence for nuclear activities shall ensure that the necessary measures are taken in order to

1. maintain safety, with due consideration to the nature of the activity and the conditions under which it is carried out;

2. safely handle and finally dispose of nuclear waste or non-recycled nuclear material arising in the activity; and

3. decommission and dismantle in a safe manner plants in which the activity is no longer to be carried out.

Section 11 The holder of a licence to possess or operate a nuclear power reactor shall, in addition to the requirements laid down in Section 10, ensure that such comprehensive research and development work is conducted as is needed in order to meet the requirements set forth in Section 10, subsections 2 and 3.

Section 12 The holder of a licence to possess or operate a nuclear power reactor shall, in consultation with other reactor possessors, prepare or have prepared a programme for the comprehensive research and development work and the other measures stipulated in Section 10, subsections 2 and 3, and in Section 11. The programme shall present a survey of all measures that may be necessary and also specify the measures that are intended to be taken within a period of at least six years. The programme shall, beginning in 1986, be submitted to the Government or the authority designated by the Government every third year for examination and evaluation.

Section 13 The obligation of a reactor possessor to defray certain costs incurred by the State and to remit an annual fee to the State is governed by provisions of the Act (1981:669) on the financing of future expenditure for spent nuclear fuel etc.

Section 14 Where a licence is revoked or the period of validity of a licence expires, the obligations under Section 10 remain in force until they have been fulfilled or waived. The obligations may be waived by the Government or the authority designated by the Government.

Revocation of licences

Section 15 A licence to conduct nuclear activities can be revoked by the authority issuing the licence if

1. conditions or directives stipulated pursuant to Section 8 or Section 9 have not been observed in some essential respect;

2. the provisions of Section 11 or Section 12 have not been observed and particular reasons exist from the viewpoint of safety; or

3. there are other very particular grounds from the viewpoint of safety.

Supervision

Section 16 Supervision to ensure compliance with this Act and the conditions stipulated or the directives issued pursuant thereto shall be exercised by the authority designated by the Government.

Section 17 A licence-holder shall, at the request of the supervisory authority

1. furnish the authority with such information and documents as are needed for the exercise of the supervision, and

2. give the authority access to the plant or site where the nuclear activity is being carried out, to the extent required for the exercise of supervision.

Section 18 The supervisory authority may prescribe such measures as are needed in order to ensure compliance with this Act or with conditions stipulated or directives issued pursuant thereto.

Public insight

Section 19 The holder of a licence to operate a nuclear power reactor or a plant for the handling, intermediate storage or final disposal of nuclear waste or of nuclear material which is not to be recycled shall give the local safety committee, appointed by the Government, insight into the operation of safety and radiation protection procedures at the plant.

Section 20 This insight shall enable the committee to gather information on safety and radiation protection measures taken or planned as referred to in Section 19 and to compile material to inform the public of this work.

Section 21 The licence-holder shall, at the request of the committee

1. furnish the committee with information on available facts and give the committee access to available documents, all to the extent necessary for the committee to perform its duties under Section 20; and

2. give the committee access to and show them plants or sites, if this is necessary in order for the committee to have information or documents furnished under subsection 1 further elucidated and provided that access is consistent with applicable safety regulations.

Penalty provisions etc.

Section 22 If a person does not comply with the provisions of Sections 10-12 or with conditions stipulated or directives issued pursuant to this Act, or fails to comply with what the supervisory authority has requested or decided pursuant to

Section 17 or Section 18, the supervisory authority may direct him to comply under penalty of a fine.

Section 23 Appeals against decisions taken by the supervisory authority under this Act shall be lodged with the Government.

Decisions taken by the supervisory authority shall become effective immediately unless otherwise decided.

Section 24 Appeals against the decisions of a local safety committee concerning requests under Section 21 shall be lodged with the County Administrative Court.

Section 25 A sentence of fines or imprisonment for a maximum of two years shall be passed on anyone who

1. conducts nuclear activities without a licence as required under Section 5 or who violates Section 6; or

2. disregards conditions stipulated or directives issued pursuant to this Act.

Matters involving the illicit conveyance into Sweden of nuclear material or nuclear waste or illicit conveyance out of Sweden of nuclear material or other equipment or materials referred to in Section 1, subsection 4, or attempts to carry out such importation or exportation, are, however, governed by the Act on penalties for the smuggling of goods (1960:418).

Section 26 Nuclear material or nuclear waste, which anyone has acquired, possessed, transferred, handled, processed, transported or otherwise had dealings with while not possessing a licence pursuant to Section 5, can be declared completely or partially forfeited, if this is not obviously unreasonable. If that person is no longer in possession of the substance, its value may instead be declared forfeited.

Section 27 Anyone who fails to comply with the requests or decisions of the supervisory authority pursuant to Section 17 or Section 18 or the requests of the local safety committee pursuant to Section 21, or who wilfully or through gross negligence furnishes the authority or the committee with incorrect information, shall be sentenced to a fine or to imprisonment for a maximum of six months.

Section 28 In case the supervisory authority has made directions in accordance with Section 22, the other penalty provisions shall not apply.

Section 29 Offences specified in the first paragraph of Section 25 or in Section 27 in respect of decisions made by the supervisory authority are indictable by a public prosecutor only at the instance of the supervisory authority.

Transitional provisions

1. This Act enters into force on 1 February 1984.

2. This Act abrogates the Act (1956:306) on the Right to Generate Atomic Energy etc. (Atomic Energy Act), the Act (1977:140) on Special Permission to Charge Nuclear Reactors with Nuclear Fuel, etc. (the Stipulatio Act), the Act (1979:335) on Prohibitions against Charging Nuclear Reactors with Nuclear Fuel during a given period of time and the Act (1980:1123) on Public Insight into the Safety Work at Nuclear Power Plants.

   The provisions of Section 4 of the Act on Special Permission to Charge Nuclear Reactors with nuclear fuel, etc. and Section 2 of the Act on Prohibitions against Charging Nuclear Reactors with Nuclear Fuel during a certain period of time will remain in force until 31 December 1989.

3. Should any Act or other statute make reference to a provision that has been superseded by a provision of this Act, the latter provision is applicable.

4. Licences as well as conditions stipulated and directives issued pursuant to the Atomic Energy Act shall be regarded as having been issued pursuant to the corresponding provision of the new Act.

5. Previous provisions shall be applicable in cases or matters that have been brought before a court or any other authority prior to the entry into force of this Act. Applications for permits under the Act on Special Permission to Charge Nuclear Reactors with Nuclear Fuel, etc. that have been filed but upon which no decision has been taken before the entry into force of the new Act shall, however, be decided under the new Act.

6. The provisions of Section 11 regarding comprehensive research and development work and of Section 12 do not apply during the period in question to holders of licences issued for a limited period of time prior to the entry into force of this Act. The licence-holder may, however, notify the Government or the authority designated by the Government during the period of validity of the licence that he undertakes to comply with the provisions of Section 12. In such a case, these provisions apply as of the date of the notification.

Swedish Code of Statutes 1984:5

ACT ON THE FINANCING OF FUTURE EXPENSES
FOR SPENT NUCLEAR FUEL ETC.
Issued 12th January 1984 (No. 5)

Section 1

Pursuant to the provisions of Sections 10 and 11 of the Act on nuclear activities (1984:3), the holder of a licence to possess or operate a nuclear power reactor (the reactor owner) shall defray, inter alia, the costs for

1. the safe handling and final safe disposal of spent nuclear fuel from the reactor and radioactive waste deriving from it;

2. the safe decommissioning and dismantling of the reactor installation;

3. the performance of the research and development work necessary for the conditions referred to under subsections 1 and 2 to be met.

Section 2

In addition to what is set forth in Section 1, the reactor possessor shall also defray the costs incurred by the State in

1. supplementing the research and development work referred to in Section 1, subsection 3,

2. deciding on matters referred to in the second paragraph of Section 5 or in Section 10 and

3. the monitoring and inspection of final repositories.

Section 3

The reactor owner shall, in consultation with other reactor owners, prepare or have prepared an estimate of the costs necessary for fulfillment of what is stipulated in Section 1. The estimated costs shall include an assessment of the costs of all measures that may be necessary as well as the costs of measures intended to be taken within a period of at least three years. The cost estimate shall be reviewed annually.

The cost estimate shall be submitted annually to the Government or to the authority designated by the Government.

Section 5

In order to ensure that funds will be available to defray the costs referred to in Sections 1 and 2, the reactor possessor shall pay an annual fee to the State as long as the reactor is in operation. As regards the costs for the handling and final disposal of spent nuclear fuel, the obligation to pay a fee shall apply to those costs that are attributable to the spent fuel after it has been removed from the reactor facility. The fee payable shall be in relation to the amount of energy delivered from the reactor facility.

The amount of the fee shall be determined annually for the following calendar year by the Government or by the authority designated by the Government.

The annual fee shall be determined so that the total of the fees paid during the operating life of the reactor cover the costs referred to in the first paragraph.

Section 6

The annual fee shall be determined on the basis of the cost calculation and the plan referred to in Sections 3 and 4 and the estimated expenses for measures referred to in Sections 1 and 2. With regard to the measures referred to in Section 1, account shall be taken of measures previously taken for the disposal of spent nuclear fuel and radioactive waste deriving from

it, the condition of the reactor facility and other circumstances that can affect the calculation of the fee.

If there are no data or the data are so incomplete that they cannot be made a basis for the calculation of the costs, the fee shall be fixed at a reasonable amount.

Section 7

The fee shall be paid to the authority designated by the Government. Collected fees shall be deposited by it in an interest-bearing account with the National Bank of Sweden. Accrued interest shall be capitalized.

Section 8

Loans may be granted to a reactor possessor out of the fees paid in by it against the provision of collateral.

Such loans shall carry interest at a rate no less than that given by the National Bank of Sweden on the collected fees deposited with it. Interest paid shall be deposited in the account referred to in Section 7 and shall be capitalized.

Loans shall otherwise be subject to such terms and conditions as are required to ensure the availability of funds for the purposes referred to in Section 9.

Section 9

Fees paid by a reactor possessor may be used in reimbursement of the costs incurred by the reactor possessor in respect of measures referred to in Section 1, subject to the limitation resulting from the provision in the second sentence of the first paragraph of Section 5, and further to defray the costs incurred by the State in respect of measures referred to in Sections 1 and 2 which are attributable to the reactor or to fuel utilized in the reactor.

Section 10

Matters relative to supplementary research and development activities, surveillance and inspection of final repositories, loans to reactor possessors out of remitted fees and the terms and conditions of such loans, as well as the application of collected fees shall be reviewed by the Government or the authority designated by it.

Section 11

Upon request, the reactor possessor shall provide such information and such documents as are necessary for the Government or the authority designated by it to establish the fee in accordance with the second paragraph of Section 5 and to review the matters referred to in Section 10. To the extent required for the aforementioned purposes, the reactor possessor upon request shall further grant access to facilities or sites where spent nuclear fuel or radioactive waste deriving therefrom is stored or handled.

Section 12

Anyone who, intentionally or through gross negligence, provides incorrect information or otherwise disregards his obligations pursuant to Section 11 shall be liable to a fine, unless the deed is punishable under the Criminal Code.

Transitional provision to the 1984 amendments

This Act enters into force on 1st February 1984

With regard to licence-holders whose licences have been issued for a limited period of time before the entry into force of the (1984) Act, Section 3 of the Act abrogated by this Act shall apply for the period in question or until the licence holder has, under item 6 of the transitional provisions to the Act on Nuclear Activities (1984:3), given notification that he undertakes to fulfil the obligations laid down in Section 12 of that Act.

APPENDIX II

Brief Description of the Swedish Parliamentary System

Background

By European standards, Sweden is a large country, almost the area of France, but with a small population of 8.5 million. The population is very unevenly distributed.

Sweden is a constitutional monarchy with a parliamentary form of government. The people elect members of the national parliament, county councils and municipal councils, with each voter casting three ballots. There is also the possibility of advisory referenda. With few exceptions, government documents are open to public and press inspection at any time.

Parliament (the Riksdag) is the principal representative of the people according to Sweden's Instrument of Government. Parliament enacts laws, decides on taxes and determines how central government funds are to be used. Parliament has oversight over the government and administration of the country. Parliament is the foundation for the democratic exercise of power through the Cabinet (the "Government").

The party or parties enjoying majority support in Parliament form the Cabinet (the Regeringen), which is the country's highest planning and administration authority.

1. Parliament

Sweden has an unicameral parliament. The whole Parliament is constituted by direct election. Parliament has 349 members who serve three-year terms.

2. The political parties

The five political parties are the Moderate Party, the Center Party and the Liberal Party, all non-socialistic, and the Social Democratic Party and the Left Party Communists. There is an almost 50/50 balance between the socialistic and non-socialistic parties in the Swedish Parliament.

3. The King

The King, since 1973 Carl XVI Gustaf, has only ceremonial functions as Head of State.

4. The Cabinet (the Government)

The Cabinet is headed by a Prime Minister who has at his side 13 heads of Ministries and 7 ministers without portfolio. The Cabinet as a whole is responsible for all Government decisions.

Energy matters are handled by the Ministry of Environment and Energy.

The Ministries are small units, each generally consisting of no more than 100 persons (perhaps comparable to the office of the secretary in U.S. cabinet departments). They are concerned with (a) preparing the Government's bills to Parliament on budget appropriations and laws, (b) issuing laws and regulations and general rules for the administrative agencies, (c) international relations, (d) appointments of officials in the administration, and (e) certain appeals from individuals, which are addressed to the Government.

5. Administrative organization

Actual implementation and enforcement of laws is entrusted to about 100 relatively independent central administrative agencies. In the energy sector there are such agencies as the Nuclear Power Inspectorate, the Radiation Protection Institute, the National Board for Spent Fuel, and the Environmental Protection Agency among others.

Every such agency is headed by a Director General, appointed by the Government (i.e., the Cabinet), as a rule for a period of six years at a time. Sometimes a Director General is chosen from political circles. The board of an agency consists of the chairman (often the Director General) and other members who may include a number of the senior officials, some parliamentarians and/or some other "laymen," representing organizations or sections of the population having special interest in the matters dealt with by the agency concerned. All board members are appointed by the Government, as are senior officials of the agencies. Personnel of lower grades are appointed by the board itself.

6. Regional and local administrations

There are two additional levels of government in Sweden, with the munipicalities as the smallest units and the county councils being regional units. All of Sweden is divided into 284 municipalities. Each municipality is located in one of the 24 counties.

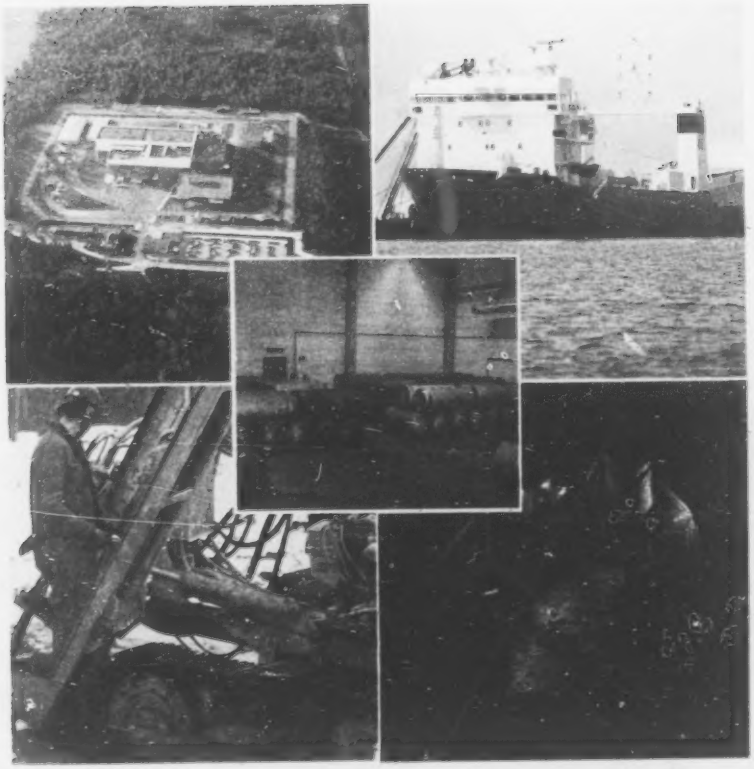
Local self-government has a long tradition in Sweden. The Local Government Act stipulates that municipalities and county councils are to "conduct their own affairs". Every municipality has a decision making body called the Municipality Council. The regional equivalent is the County Council. The regular and deputy members of these bodies are directly elected by the people at general elections every three years, on the same day as the parliamentary elections.

Appendix III

Swedish Nuclear Fuel and Waste Management Company—Activities

SKB

SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY

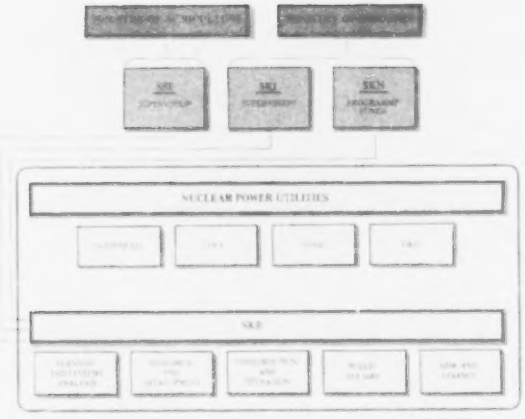


ACTIVITIES

SKB – SWEDISH NUCLEAR FUEL AND W

Svensk Kärnbränslehantering AB, SKB (Swedish Nuclear Fuel and Waste Management Company), has been given the assignment by the Swedish nuclear power utilities to develop, plan, build and operate facilities and systems for the management and disposal of spent nuclear fuel and radioactive waste from the Swedish nuclear power stations.
SKB is also in charge of the extensive research activities within the field of nuclear waste which, according to Swedish law, is the responsibility of the Swedish nuclear power utilities.

SKB handles matters pertaining to prospecting, enrichment and reprocessing services as well as stockpiling of uranium for the Swedish nuclear power industry and provides assistance at the request of its owner utilities in uranium procurement.
SKB is owned by the power utilities in Sweden that produce electricity in nuclear power stations: Forsmarks Kraftgrupp AB (FKA), OKG Aktiebolag, Sydsvenska Värmekraft AB (SVAB, owned by Sydkraft AB, South Sweden Power Supply) and Vattenfall (the Swedish State Power Board).



SKI — National Institute of Radiation Protection, SKI — Swedish Nuclear Power Inspectorate, SKN — National Board for Spent Nuclear Fuel

Board

Members of the Board

Carl-Erik Nyquist, Director General
Swedish State Power Board
Chairman of the Board

Ingvar Wivstad, Vice President
Swedish State Power Board

Lars Gustafsson, President
Forsmarks Kraftgrupp AB

Göran Ahlström, President
Sydkraft AB
(South Sweden Power Supply)
Vice Chairman of the Board

Lennart Fogelström, President
OKG Aktiebolag

Deputy members

Stig Sandklef, Chief Engineer
Swedish State Power Board

Jörgen Holdo, Financial Director
Swedish State Power Board

Olof Wikström, President
Gullspångs Kraft AB

Leif Josefsson, Vice President
Sydkraft AB
(South Sweden Power Supply)

Birger Almgren, Chief Engineer
OKG Aktiebolag

Auditors

Bertil Edlund, Chartered Public Accountant
Öhrlings Revisionsbyrå AB

Vacant

Deputy auditors

Sigvard Heurlin, Chartered Public Accountant
Öhrlings Revisionsbyrå AB

Hans Lundqvist, Chartered Public Accountant
Malmö

WASTE MANAGEMENT COMPANY

The Swedish Nuclear Fuel and Waste Management Company (SKB), previously the Swedish Nuclear Fuel Supply Company, was formed in 1972, principally to work with matters relating to supplying the Swedish nuclear power stations with nuclear material and services within the nuclear fuel cycle.

Since then, a shift of emphasis has taken place within the company so that the dominant activities today are associated with the management and disposal of spent nuclear fuel and radioactive waste.

The basis of SKB's planning and activities is the Swedish nuclear programme and what Parliament has decided concerning future Swedish nuclear power production.

This programme entails the handling and storage of spent nuclear fuel and radioactive waste from twelve nuclear power units with a total capacity of 9 500 MW, which are not to be operated beyond the year 2010.

As from 1985 45—50% of the electricity produced in Sweden will be generated by nuclear power stations.

According to Swedish law the nuclear utilities have the responsibility for measures needed to realize a safe system for the handling and final disposal of spent nuclear fuel and waste. This responsibility also includes the financing of the total costs.

The nuclear power utilities have delegated to their jointly owned company, SKB, the coordination, planning, design, construction, and operation of the facilities needed as well as the necessary R&D work.

The completion of the above-mentioned twelve-reactor programme during 1985 entails a transition for the SKB owners from an intensive period of construction to a more operational period. To some extent this is also the

case for SKB. A number of important goals have been achieved in recent years. These include comissioning of a transportation system for spent nuclear fuel including a special ship (Sigyn), construction of the CLAB (Central interim storage facility for spent fuel) and approval of the KBS 3 disposal method as a basis for the Government's fuelling licence for the F3 and O3 reactors at Forsmark and Oskarshamn, respectively.

Ongoing construction projects are the final repository for low- and medium-level waste, SFR, which is under construction at Forsmark and the associated transportation system for low- and medium-level waste.

Important objectives for SKB in the future will be, in cooperation with the owners, to operate the storage and disposal facilities and transportation system in a manner acceptable to society at optimum efficiency and minimum cost.

Particularly important is the R&D work, which will be conducted for the purpose of further developing and testing various options for the final disposal of spent nuclear fuel and other long-lived radioactive waste. Great importance is attached to international research cooperation.

Sweden today is completely dependent on imports of uranium and certain services within the nuclear fuel cycle.

The emphasis of SKB's future front-end activities will be on supply problems of a common nature faced by the power utilities. Together with its owners, SKB shall also work for effective action and cooperation to ensure security of supply and good economy.

Stockholm, November 1985

Sten Bjurström
President

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Nuclear fuel supply 4
The transportation system 6
Interim storage in the CLAB 8
Final repository for reactor waste — SFR 10
Final repository for high-level and long-lived waste — SFL 12
International research cooperation 14
The costs of the nuclear fuel cycle 15

NUCLEAR FUEL SUPPLY

The Swedish nuclear power programme has an annual natural uranium demand of about 1 300 metric tons. Most of this demand has been covered up to 1990 through long-term contracts between the nuclear power utilities and producers in Canada and Australia. The necessary enrichment of the uranium takes place at plants in the United States, the Soviet Union and France.

Within the nuclear fuel supply area, SKB is charged with analyzing demand etc, arranging for coordinated uranium purchases, representing the power utilities in certain matters of joint interest, and providing for strategic stockpiling and uranium prospecting in Sweden.

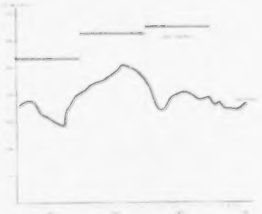
Sweden's supply of uranium today is based entirely on imports. Present-day suppliers are found in Australia, Canada, the United States and France. France supplies uranium from Niger and Gabon in Africa. Approximately 90% of the deliveries are made under long-term contracts. Canada is responsible for about 50% of the deliveries. Up to 1990, the demand amounts to about 7 800 metric tons, of which 6 800 tons had been contracted for in the middle of 1985.

Natural uranium is normally delivered in the form of uranium concentrate. The concentration of fissionable material in the form of uranium-235 in natural uranium is about 0.7%. In order for natural uranium to be used for nuclear fuel in the Swedish light-water reactors, it must be enriched to a uranium-235 concentration of about 3%. This is done in an industrial process where the crude uranium is converted to uranium hexafluoride, which is then enriched. Sweden contracts for conversion services in Canada, the United States, England and France. Enrichment is done in the USA, the USSR, at Eurodif's plants in France and at Urenco's plants in Holland, England and West Germany.

Sweden has considerable uranium resources. Most of the proven reserves consist of relatively low-grade shale deposits (Ranstad) with about 300 g uranium per ton of shale. These deposits are not exploitable at the present-day low price of imported uranium.

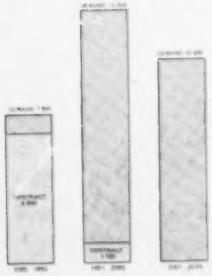
Uranium also occurs in relatively high concentrations in certain parts of the Swedish Precambrian rock. SKB is therefore conducting prospecting at a number of places within the bedrock in the northern part of Sweden. Mineralizations of at least 6 000 metric tons of uranium have been found with concentrations higher than 1000 g per ton. These ores constitute important reserves for the future.

Uranium is currently offered on the world market at favourable prices, so no mining surveys are being conducted today by SKB.



The figure shows the price for long-term contracts on the one hand and the spot price on the other hand. The long-term price is the average price for imports to the European Community. The spot price is the market quotation according to the West German company NUKEM.

Eurodif's plant for uranium enrichment at Tricastin in France.



Of the Swedish natural uranium demand up to 1990, 6 800 metric tons had been contracted for as of mid 1985. The relationship between demand and contracted supply for the coming decades is shown above.

The uranium plant at Key Lake, Saskatchewan, Canada, from which uranium is delivered to Sweden.

Containers of enriched uranium in SKB's strategic stockpile. Uranium in strategic stockpiles, under fuel fabrication and at the nuclear power stations is sufficient for about two years of operation.

Uranium deposits have mainly been found at Ranstad and at Lilljuthatten. During 1983, SKB prospected in Arjeplog, Arvidsjaur, Boden, Ange/Härjedalen, Åsele and Östersund/Ragunda as well as in the area around Lilljuthatten.

5

THE TRANSPORTATION SYSTEM

Every year, 20—30% of the fuel assemblies in the Swedish reactors are replaced, which means that a total of about 250 metric tons of spent nuclear fuel (calculated as uranium) must be taken care of. The fuel is first stored for at least one year in a storage pool at the reactor, after which it is transported for central interim storage in the CLAB facility (central storage facility for spent fuel).

Spent fuel and other radioactive waste is transported by sea by the specially-designed ship Sigyn. During transport, the highly radioactive fuel is kept in radiation-shielded casks weighing 80 tons and able to hold approximately 3 tons of fuel.

The transport casks protect the environment from harmful radiation and the transported fuel from damage. The casks are extremely strongly built and can withstand falls from high heights, immersion to great water depths, heating etc. without losing their integrity. The transport casks meet the international regulations and recommendations issued by the IAEA (The International Atomic Energy Agency in Vienna).

All Swedish nuclear power installations, as well as CLAB, are located along the coast. A sea transport system has therefore been built up, consisting of the ship and terminal transport vehicles which convey the transport casks from the ship's hold to the various facilities and vice versa. The same ship and the same type of vehicle will be used later for transporting low- and medium-level wastes from the nuclear power stations to the final repository for reactor waste — SFR. Such waste is transported in a simpler type of transport cask which, however, will have about the same weight with contents as the fuel casks.

M/S Sigyn, which was used during 1983 for fuel shipments from Sweden to France, is a combined roll-on/roll-off & lift-on/lift-off vessel, which means that the cargo can either be driven directly into the hold via an opened stern ramp or lifted on board by means of shore-based cranes. In roll-on/roll-off handling, which is the normal method used at the Swedish plants, the aforementioned transport vehicle is used in order to make the handling fast, safe and efficient.

The ship is built for unrestricted worldwide service and is specially designed for her purpose. Machinery, electrical system etc. are duplicated for higher reliability and the cargo hold is surrounded by a double hull and a double bottom. This ensures very high floatability and protects the cargo in the event of a serious collision or grounding. After one year's operating experience, a few minor modifications have been made — the bow thruster has been duplicated, making the ship easier to manoeuvre in narrow harbours.

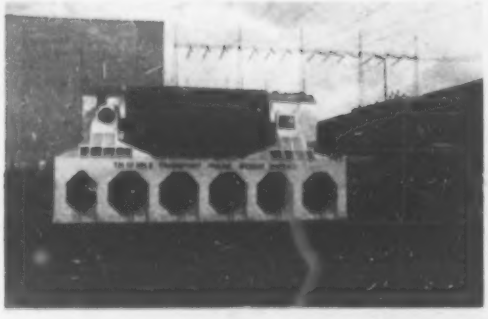
△ *M/S Sigyn is a ship for transporting spent nuclear fuel and other radioactive material. Length 90 metres, breadth 18 metres and draught 4 meters. Payload capacity max. 1 400 metric tons.*

Containers made of steel are used for transporting medium-level waste from reactor operation.

The main components of the transport cask are body, with stainless steel lining, copper fins for heat dissipation, neutron shield lid system with shock-absorbing covers at both ends, removable basket of neutron-absorbing material with channels for the fuel assemblies and lifting trunnions.

The sea transports of spent nuclear fuel and radioactive waste will entail approximately 30 trips a year starting in 1985 for M/S Sigyn from the Swedish nuclear power stations to the CLAB at Oskarshamn and as from 1988 to the SFR at Forsmark.

A transport vehicle accompanies the ship and is used for loading and unloading and terminal handling of the transport casks.
While in transit, the transport cask is placed on a load carrier, which acts as a transport frame as well as a support for the cask while parked awaiting further transport. The transport vehicle is manoeuvred in under the load carrier and lifts it when the bed is raised hydraulically.



INTERIM STORAGE IN THE CLAB

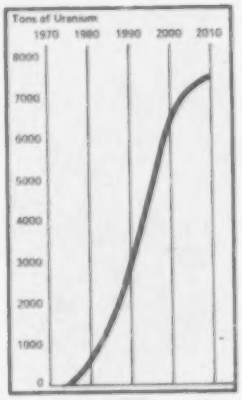
The Swedish system for the management and disposal of spent nuclear fuel is based on interim storage for 30—40 years prior to final disposal. For this purpose, SKB has built the CLAB facility. The fuel storage pools at the nuclear power stations have a capacity to store spent fuel from 3—8 years of operation. In order to expand capacity for storing fuel over a longer period of time, a central storage facility for spent fuel, CLAB, has been built adjacent to the Oskarshamn power station. The CLAB is able to receive fuel from all Swedish nuclear power stations for intermediate storage for a period of 30—40 years before final disposal can be commenced (see the SFL section).

Construction work on the CLAB facility at Simpevarp was begun in 1980 and the facility received fuel for the first time in July 1985. The storage pools now built can hold 3 000 metric tons of spent fuel, which is enough up until the mid 1990s. One or two additional expansions are required in order for all fuel from the 12 reactors to be accomodated — 7 500 metric tons (uranium).

Receiving of the transport casks containing the spent fuel takes place in the CLAB in a surface building, while storage takes place in pools in a rock cavern whose roof is located about 25 m below ground level. Facilities for power supply, water treatment, ventilation, personnel quarters etc. are also located on the surface. Communication with the rock cavern is provided through well-protected shafts. All handling and storage of the fuel assemblies will take place under water, which functions as a radiation shield while simultaneously cooling the fuel. Transport down to storage will also take place in a water-filled container that runs in its own elevator shaft.

The total cost for erecting the CLAB is estimated at about SEK 1 700 million, at the 1985 price level, distributed equally between design, civil construction and systems installations.

When finished, the CLAB will have an operating staff of about 70 persons. OKG AB has been subcontracted by SKB to be locally responsible for operation of the CLAB.



The estimated total quantity of spent nuclear fuel from the Swedish nuclear power programme contains approximately 7 500 metric tons of uranium. The figure shows how the quantity of spent nuclear fuel increases with time.

On the surface, the CLAB consists of a receiving section for receiving and unloading of incoming transport casks. The storage cavern is located 25 metres below the surface. It is 120 metres long, 21 metres wide, 27 metres high and contains four water-filled pools for fuel storage and a central pool that connects to a transport shaft.

The CLAB's receiving hall. The excavation and civil engineering work began in May 1980. The construction work is now concluded and the facility started operating in July 1985.

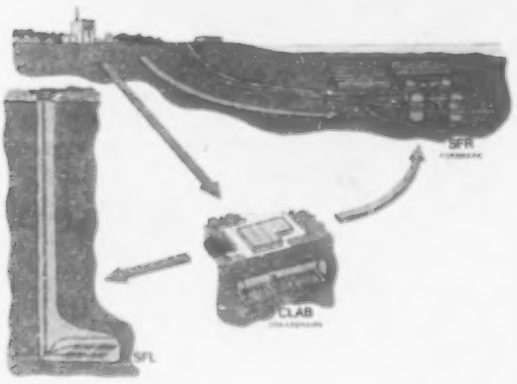
The storage pools are made of concrete, lined with stainless steel. Each pool holds 5 000 m³ of water and 750 tons of spent fuel standing in storage canisters.

After about a year of storage in the fuel storage pools at the nuclear power stations, the spent nuclear fuel will be taken to the CLAB interim storage facility.

The CLAB constitutes an extension of the nuclear power stations' fuel storage pools. But the facility is operated separately and is completely independent of operation at the nuclear power stations. The CLAB will be operated even after the nuclear power stations have been decommissioned.

During storage in the CLAB, the activity and heat flux of the fuel decays. It therefore becomes easier to handle when the time comes to transfer it to the SFL for final disposal around the year 2020.

The low- and medium-level waste that results from operation of a nuclear power reactor is temporarily stored at the nuclear power stations. At present, a final repository for reactor waste — SFR — is being constructed.



FINAL REPOSITORY FOR REACTOR WA

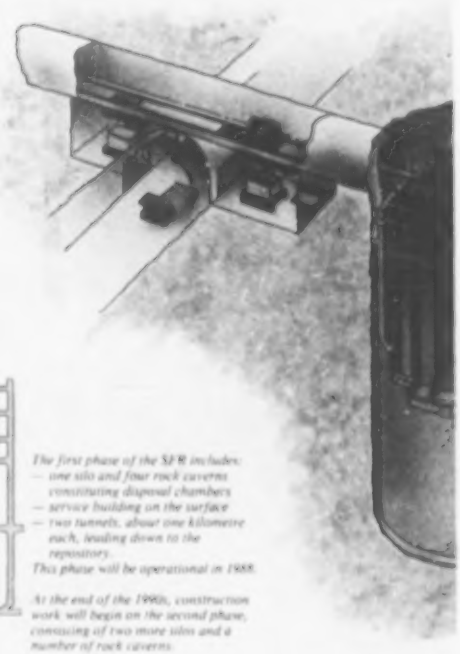
The SFR is being built adjacent to the Forsmark nuclear power station and will accommodate the Swedish nuclear power industry's low- and medium-level operating waste, so-called reactor waste. Most of the reactor waste consists of filters and ion exchange resins that have been used for cleaning the water systems in the nuclear power stations. A small amount of similar radioactive waste from other industry, research institutions, and hospitals will also be disposed of in the SFR.

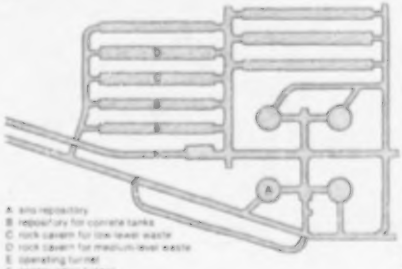
The activity of the low- and medium-level waste that is to be disposed of in the SFR will have declined to a harmless level after about 500 years.

The entire repository section is situated in rock, 50 metres below the seabed. The rock on the repository site is of such quality that stable caverns with large spans can be excavated there. The horizontal sea-level above the repository eliminates the driving force for groundwater flow in the fissures of the rock mass. The groundwater around the repository will thus be nearly stagnant. The water depth is also sufficient so that the rock will not rise above the surface of the water due to the ongoing land uplift within the next 1 000 years.

In March of 1982, SKB applied to the Government for a licence to build a final repository for reactor waste, SFR, at Forsmark. On 22 June 1983, the Government granted the licence, and in August of the same year construction work on the repository started.

The repository will consist of rock





A. silo repository
B. repository for concrete tanks
C. rock cavern for low-level waste
D. rock cavern for medium-level waste
E. operating tunnel
F. construction tunnel

The first phase of the SFR includes:
— one silo and four rock caverns constituting disposal chambers
— service building on the surface
— two tunnels, about one kilometre each, leading down to the repository.
This phase will be operational in 1988.

At the end of the 1990s, construction work will begin on the second phase, consisting of two more silos and a number of rock caverns.

caverns of differing design, depending on the type of waste to be disposed of there. The medium-level waste, which contains most of the radioactive substances, will be deposited in concrete silo-like structures situated inside a cylindric rock cavern and isolated from the rock by a layer of clay (bentonite).

The low-level waste isdeposited directly in rock caverns designed for the particular type of containers being used for such wastes.

The total waste volume is estimated at 90 000 cubic metres. The SFR will be built in two phases. The first phase will be completed and commissioned in 1988, the second is planned for the end of the 1990s.

Blasting work for the entrance tunnels to the SFR began in August 1985. In the beginning of 1985 the two tunnels reached the storage area one kilometre outside the harbour at Forsmark.

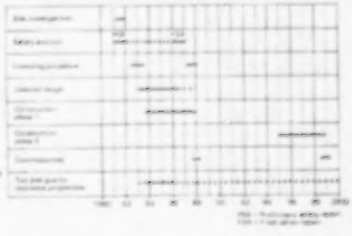
Since the silos will contain most of the radioactive substances in the SFR, they have been provided with the most qualified barriers. They consist of the waste package itself and a concrete backfill, the silo wall of concrete, the clay fill between the silo and the rock and, finally, the surrounding rock mass.

During the construction period, a testing and demonstration programme will be conducted including studies of both waste and barriers. A series of laboratory experiments will be carried out in 1985 and later followed up with test series. The testing programme will provide more detailed information on groundwater movements in the rock and the protective capacity of the other barriers in the given environment.

The probable level of the actual dose from the SFR is less than 1/1 000th of the natural background radiation in the area today.

The licence application for the SFR was based on a preliminary safety report from SKB. The report has been reviewed by the Swedish Nuclear Power Inspectorate and the National Institute of Radiation Protection. A final safety report will be submitted to the authorities for review and approval before the repository is taken into service.

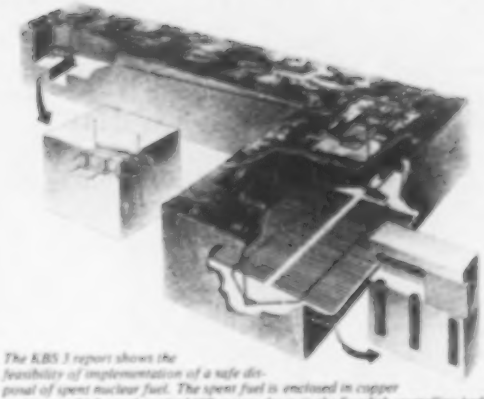
The total cost of the SFR is estimated at SEK 1 250 million. This is broken down into SEK 950 million in construction costs, SEK 240 million in operating costs up to the time all the waste has been deposited and SEK 60 million in sealing costs, all in 1985 prices.



The SFR is being constructed in two phases. The first phase will be commissioned in 1988. Phase 2 will be built at the end of the 1990s.

FINAL REPOSITORY FOR HIGH-LEVEL

According to Swedish law, the nuclear power utilities are obligated to ensure that the radioactive waste products of nuclear power are disposed of in a safe manner — in both the short and the long time perspective. The function of the Government and national authorities in this context is to lay down the safety requirements and to regulate and supervise the activities of the power utilities.



The KBS 3 report shows the feasibility of implementation of a safe disposal of spent nuclear fuel. The spent fuel is enclosed in copper canisters, which are deposited 500 metres down in the Swedish crystalline bedrock. Both natural and engineered barriers prevent the radioactive substances from reaching the biosphere in harmful concentrations.

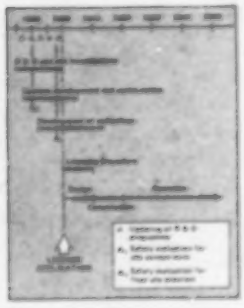
The Act on nuclear activities that entered into force on 1 February 1984 contains, like previous legislation, requirements that new reactors may only be taken into operation if the owner has demonstrated a method for safe handling and disposal of the spent nuclear fuel. The Act also requires that the reactor owners produce a plan for the research and development work that is required to implement the final disposal scheme. The plan shall be updated for review and submitted every three years to the authorities.

The research report KBS 1 was presented to the Government in November 1977 together with an application for fuelling permission for Ringhals 3 and Forsmark 1 and later also Ringhals 4 and Forsmark 2. It was based on the assumption that the spent nuclear fuel would be reprocessed, which was then regarded as a preferable option.

The following year KBS 2 was published, which was based on direct disposal of the spent nuclear fuel without prior reprocessing.

KBS 3 — which was appended to the fuelling permit application for Forsmark 3 and Oskarshamn 3 and submitted to the Government in May 1983 — proceeded further with the method introduced in KBS 2, but with a much broader base of knowledge and resulting modifications.

In June 1984, the Government granted fuelling permission on the basis of the KBS 3 report and after extensive domestic and foreign specialist review. The Government has thereby arrived at the conclusion that the Swedish reactor operators have satisfied the requirements of the Act by demonstrating that a method exists for the handling and final disposal of spent nuclear fuel and radioactive waste deriving from it which is acceptable with regard to safety and radiation protection.



Overall timetable presented in SKB's programme for research and development. The timetable presumes that a site for the final repository will have been chosen and approved by the authorities by the year 2010.

Four fundamental principles

The Swedish nuclear waste management programme is characterised by:

- very high safety requirements, both in a short and a long time perspective
- the use of technology available today
- the greatest possible independence of other countries
- no burdens on future generations

In principle, final disposal according to KBS 3 is simple: The spent nuclear fuel is encapsulated in tight copper canisters, which are deposited 500 metres down in the crystalline bedrock. When the repository is full, all shafts and tunnels are backfilled and sealed, after which the repository does not require any further surveillance. The safety of the repository is based on the fact that degradation of the canisters and subsequent transport of their contents with the groundwater to the surface of the ground will take such a long time that the radioactive substances will decay and be diluted to such a degree that they reach the biosphere only in harmless concentrations.

Site investigations

Under the management of SKB test

AND LONG-LIVED WASTE – SFL

drillings are being conducted in the bedrock in order to gain further knowledge of the geological conditions prevailing on different potential disposal sites.

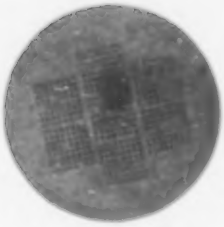
The primary objective is to study the properties of the bedrock, the pattern of fracture zones and the physical and chemical conditions of the ground water. The investigations are performed in and adjacent to rock formations that can be expected to be large enough to host all the spent fuel, around 7 500 metric tons, that has been generated up to the year 2010. The geological conditions play a decisive role in the final choice of repository site. But demographic factors, transport conditions and economics must also be taken into consideration. All of this justifies investigating a large number of areas in order to obtain comprehensive knowledge and data to serve as a solid basis for a sweeping analysis and strong decision some time around the turn of the century.

Encapsulation of the fuel

Once the site has been chosen and the facility is ready to receive the spent nuclear fuel, it will be transferred from the CLAB interim storage facility at Oskarshamn to the final repository.

Prior to final disposal, the fuel assemblies will be encapsulated in copper canisters which will then be lowered into the repository about 500 metres down in the rock.

Sites which SKB has investigated during the period 1977—85.



In the repository, the canisters will be placed in vertical deposition holes drilled from the floor of the repository tunnels. In each deposition hole, the canister will be surrounded by a layer of highly compacted bentonite clay. In this manner, the fuel will be isolated from the biosphere by a series of barriers that interact with and complement each other. The copper canister protects against mechanical forces and radiation during handling. When the canister has been deposited in the deposition hole, it prevents groundwater from coming into contact with the spent fuel for a very long period of time. The bentonite clay limits the flow of water around the canister. The rock itself retards the radionuclide migration and protects against both natural and human intrusion such as future ice ages and acts of war.

Cross-section of a copper canister with seven simulated fuel assemblies from a boiling water reactor. A steel canister with lid and filled with fuel and copper powder has been compressed under high temperature and pressure into a solid unit.

Schematic diagram of a canister in its deposition hole, surrounded by blocks of highly compacted bentonite clay. The tunnel has been backfilled with a mixture of sand and bentonite.

The site investigations in the first phase cover some ten sites and will be carried out up to about 1990.

RESEARCH – COOPERATION

The waste problems associated with nuclear power are urgent and topical questions in all countries with nuclear power programmes. The expansion of nuclear power has also led to comprehensive R&D activities concerning nuclear waste in many countries. International cooperation within the field is well developed and proceeds on several levels, through agreements between individual countries and within the framework of international organizations. In order to streamline and broaden Swedish research, Sweden has established an extensive international exchange of research findings and practical experience.

Intensive Swedish efforts in recent years in the field of research and technology for the handling and disposal of nuclear waste — exemplified by the CLAB, SFR and KBS projects — have put Sweden in the forefront today on many matters in this field. This is particularly true of research on geologic disposal in crystalline bedrock, where a number of countries have expressed their interest in establishing joint research under various forms.

Research agreements have been signed with the U.S. Department of Energy — DOE, Atomic Energy of Canada Ltd — AECL, NAGRA of Switzerland and Commissariat à l'Energie Atomique — CEA, France. Annual meetings for information exchange and joint ventures undertaken in cooperation with these organizations are important complements to SKB's own programme.

Exchange also takes the form of placing guest researchers at institutions in other countries.

An information exchange also takes place with the EEC's special group for radioactive waste and various Japanese organizations. SKB participates in the OECD/NEA information system for data on the migration of radionuclides in rock.

Moreover, SKB participates in various committees on nuclear waste etc. within the IAEA and the OECD/NEA. SKB is a member of the Atomic Industrial Forum in Washington and the Uranium Institute in London.

The STRIPA project has been pursued in an abandoned iron ore mine at Stripa in Västmanland since 1977. Field tests are conducted here on a large scale and under realistic conditions at a depth of 350 metres in the granitic rock surrounding the ore formation. The research is organized in the form of an autonomous OECD/NEA project, with SKB in charge of the management of the project. Participating countries are Canada, Finland, France, Great Britain, Japan, Spain, Sweden, Switzerland and the USA.

Japan, Switzerland and Sweden are conducting joint studies within the JNS project on the process of corrosion and dissolution in high-level radioactive glass from reprocessing. The test species are supplied by CEA, France. Most of the studies are being conducted at Studsvik Energiteknik AB and certain tests are being performed at ETR in Switzerland. The project is being managed by SKB and advisory experts from the USA, France and West Germany are participating.

A research station is being built at Lac du Bonnet in Manitoba, Canada, for research on the disposal of radioactive waste in the Canadian Precambrian Shield. A comprehensive research programme concerning groundwater conditions on the site is included in the project. SKB is participating in the evaluation.

Considerable international interest has been shown in Swedish technology and research concerning the management and disposal of nuclear waste. Therefore the nuclear power utilities' company for international consulting, SwedPower Service AB has, together with SKB, established a special group for coordinating and marketing Swedro's collective know-how and experience within this field. The members of this group also include associated groups at universities and institutes of technology, consulting firms, research organizations etc. Contracts have so far been obtained from Finland and Switzerland.

The photograph shows a rock cavern in granite at a depth of 400 m at the Nevada Test Site in the USA. In a demonstration test, the U.S. Department of Energy — DOE — has emplaced spent nuclear fuel in deposition holes and studied the effects of radiation and heat flux on the rock and the canisters.

COSTS OF THE NUCLEAR FUEL CYCLE

The total cost of the nuclear fuel cycle includes costs from uranium mining to the fabrication of the fuel as well as costs for handling, storage and final disposal of spent fuel and radioactive waste, including decommissioning and dismantling of the reactor installations.

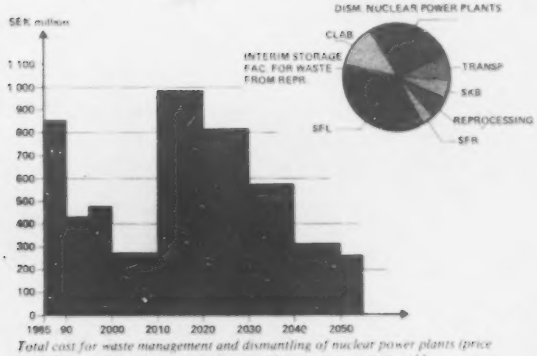
For 1984, the costs of fabricated nuclear fuel (front end) have been calculated to be SEK 0.037 per kWh of generated electricity. The costs for the management and disposal of spent fuel and radioactive waste (back end) as well as dismantling of the nuclear power stations have been estimated to be about SEK 0.020 per kWh. Of this, SEK 0.019 consists of a fee paid to a government fund, while SEK 0.001 per kWh is being set aside internally within the nuclear power utilities for the final disposal of low- and medium-level active waste.

The costs for the front end of the nuclear fuel cycle in 1984 prices are roughly as follows:
(At an annual production of about 49 TWh)

	SEK/kWh	per year (SEK million)
Natural uranium	0.013	640
Conversion	0.001	50
Isotope enrichment	0.016	780
Fuel fabrication	0.006	290
Strategic stock pile	0.001	50
	0.037	1810

Despite the large amounts of money involved here, a comparison with equivalent electricity production in a coal-fired condensing power plant shows that the nuclear fuel costs about 20% of the equivalent quantity of coal.

The total costs for managing and disposing of spent nuclear fuel and radioactive waste from the Swedish nuclear power programme have been estimated at SEK 47 billion in 1985 prices. This calculation also includes dismantling of the nuclear power plants and final sealing of the repositories around the year 2060, as well as the costs of reprocessing of around 10% of the spent fuel. The reprocessing option is still being considered even if the present preference is the direct disposal route.



Total cost for waste management and dismantling of nuclear power plants (price level January 1985). In the circle diagram, the costs are apportioned by object/purpose.

In order to cover the future costs for management and disposal of spent nuclear fuel etc, including dismantling of the nuclear power plants, the nuclear power producers are paying a fee to a special government fund under the terms of the Financing Act.

The fee is based on a "scenario" drawn up by the nuclear power utilities through SKB, which is presented annually together with a cost estimate to SKN (National Board for Spent Nuclear Fuel). After examining SKB's report, SKN makes a recommendation to the Government concerning the fee for the coming year.

The fee for the costs falling under the Financing Act for 1985 is SEK 0.019/kWh. These costs are broken down as follows:

	SEK/kWh
Intermediate storage of spent fuel	0.0047
Transports	0.0013
Reprocessing	0.0037
Final disposal of spent fuel	0.0037
Dismantling	0.0036
SKB, general costs	0.0020
	0.019
Final disposal of reactor waste	0.001

Up till January 1985 the SKN fund amounted to SEK 1 824 million. With the fee unchanged and normal operation at all the power plants SEK 1 200 million will be put into the fund each year.

SKB's costs and investments

Most of SKB's costs and investments concern activities related to the disposal of high-level nuclear waste. These expenses are covered by funds from the reserve within SKN. Other costs for SKB activities are covered through owner contributions.

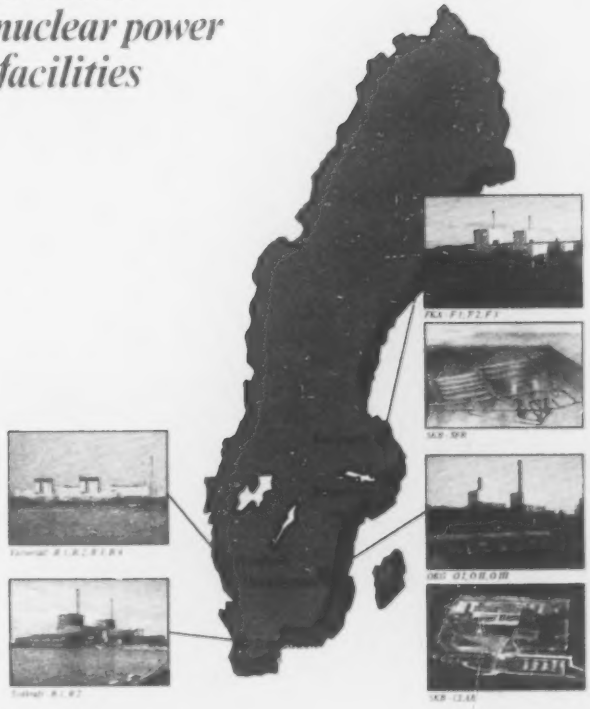
For 1984, SKB's turnover is broken down as follows:

Operating expenses	SEK Mill. (approx)
Research & development	60
Operation of transportation system	55
Reprocessing services	3
Strategic stockpiling	4
Prospecting	12
Enrichment services	221
Other expenses	29
Total	387

In 1984 SKB invested SEK 860 million in i.a. the CLAB, the SFR and the Transportation system.

Investments (total)	SEK Mill.
CLAB	1725
SFR	830
Transportation system	200

Sweden's nuclear power facilities



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